TREE CARE

THE MACMILLAN COMPANY
NEW YORK • CHICAGO
DALLAS • ATLANTA • SAN FRANCISCO
LONDON • MANILA
IN CANADA
BRETT-MACMILLAN LTD.
GALT, ONTARIO

TREE CARE

by

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New York
THE MACMILLAN COMPANY
1919

JOHN M. HALLER 1919

Published simultaneously in Canada

Printed in the United States of America

Library of Congress catalog card number: 57-6355

This book is affectionately dedicated
to my mother.

FOREWORD

TREES' LIVES and men's lives are inextricably interwoven. Without trees man would never have advanced from savagery; indeed, he might never have existed at all. Our complex modern civilizations rest on trees as solidly as a house rests on its underpinnings.

Most of us are aware of the usefulness of trees and many of us appreciate their beauty, but not all of us realize that they need to be cared for intelligently and systematically, quite as much as automobiles or teeth or children. Too many persons still regard a tree as something put there by Providence and therefore able to fight its battles without our help.

Actually, the need for tree care is increasing, not diminishing. As population grows, trees are damaged and destroyed. Communities expand and highways proliferate at the expense of the original inhabitants—the trees.

The first step in the preparation of a building site is the clearing of the ground. Cities and trees are thus antagonistic in principle and purpose. The few trees which manage to survive the onward and outward march of a metropolis and those which are later planted in atonement for original sin grow under conditions far less favorable than trees growing in their native woods. Hence, the need for care is greater.

Anyone with the good fortune to own a grove of trees or a few specimens, or even a single tree, has a moral obligation to give them the best of care. Some of that care the owner can supply himself. Many times, however, he needs the services of a professional arborist. The present book should help him to determine how much he himself can do and how much he should hire done.

Methods of tree care are being revolutionized by recent findings in the fields of antibiotics, plant hormones, organic insecticides, and chemotherapy. As new substances are tested and techniques are improved, treatments for tree troubles are constantly modified.

This does not mean that basic principles have in any way been invalidated. What may be called the mechanical aspects of tree care, such as planting, bracing, pruning, and cavity repair, have altered little in the last ten years. But the chemical aspects of treatment for diseases have changed radically.

This book has been written for tree owners. Its aim is to present the basic principles of tree care in the light of modern knowledge, and to bring within the limits of one volume the important new information that has hitherto been scattered through publications for the specialist.

Having freely given these acknowledgments, the author wishes to express particular gratitude to his original source material: the trees themselves, the many wonderful, unsung, anonymous trees which down through the years have felt the touch of his hand and supported the weight of his body.

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TREE CARE

I

STRUCTURE AND PHYSIOLOGY OF THE TREE

A TREE, like a rosebush, a cornstalk, a dandelion, or a sunflower, is a plant, resembling these other plants far more than it differs from them, even though at first sight it may not seem to do so. In all essential points a sunflower and an oak tree are alike; both consist of a spreading root system, an upright stem, and a multiplicity of leaves; both produce flowers, fruit, and seed; both are nourished by the same elements; both respond the same way to their environment; both reproduce according to the same mechanism; both live their appointed span and die. Actually, in the eyes of the botanist, the oak tree is less highly evolved than the sunflower, and the redwood is far less advanced than the dandelion.

If we could understand all the laws governing the existence of a grain of sand, wrote Einstein, we could understand the universe. Similarly, we may say that if we understood perfectly the structure and physiology of the humblest of created organisms—the microscopic one-celled plants—we would understand equally well the workings of the largest and most imposing monarch among the sequoia groves. So insignificant is mere difference in size when regarded from a strictly scientific standpoint.

Yet in spite of all this, trees remain differentiated from the rest of plants in several important respects. In an artistic, inspirational, and practical sense trees belong in a world apart. They are the predominant feature in any landscape. They preëmpt the eye of the beholder and by their very size force themselves upon his attention, willy-nilly, while smaller plants are passed unnoticed or crushed underfoot.

Trees are distinguished from other plants mainly because of their size, their hardness, and their longevity, although none of these factors belongs exclusively to them. Some kinds of bamboo and many kinds of vines are as tall as or taller than the average tree; some kinds of shrubs possess parts almost as hard and woody; many kinds of perennials live as long or nearly as long as some trees. Nevertheless, it is the combination of these three factors—size, woodiness, and longevity—that makes up our conception and definition of a tree. Few other kinds of plant can approach the life span of some of the oaks, which frequently exceeds 500 years, or of the slow-growing yews, of the Douglas firs, of the millenniary olives of Jerusalem, to say nothing of the redwoods and giant sequoias and the immensely old *ahuehuetes* (cypresses) of southern Mexico. Nor can any other plant equal in size and dignity the oaks, the firs, the pines, the eucalypti. What other plant, for example, can spread *itself out like* the Indian banyan-tree, a single specimen making a *small forest;* or what plant can soar upward with the amazing verticality of a redwood or a eucalyptus, some species of which approach 400 feet? Nor can any other plant equal in hardness or durability[1] the ebony, the *palo de Brasil,* the *quebracho,* or the lignumvitae.

Among the various definitions of a tree essayed by various writers, none is perfect, although most of them are approximately correct. To mention a few:

"A tree is a woody perennial."
"A tree is a plant of at least 15 feet in height with a single trunk."
"A tree is a perennial plant with woody stem and boughs."

And the writer's own definition:

"A tree is a plant that stands of itself and can be climbed in."

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[1] The very word *durability* is derived from a Greek word meaning *oak tree.* (Wyld: *The Universal Dictionary of the English Language.* See also *dryad, druid, tree.*)

This last definition is perhaps the best, since it incorporates the one feature that at once serves to distinguish a tree from any other plant in the minds of all those not burdened by dictionary definitions—the fact that it can be climbed in. Many vines may be climbed *up* but not *in;* nor do they stand of themselves. Many shrubs and reed-like things grow tall but cannot be climbed in. But once a plant has acquired the necessary size, shape, and rigidity to permit men (or boys) to climb about in its branches, then it is unequivocally a tree.

From the time they germinate until the time they die, trees are inescapably rooted to one spot. Except in the relatively few cases where gardeners transplant them or the even rarer cases where a river may undermine a small island of them and carry them downstream to a new lodgment, trees never move. Their cradle, their nursery, their playground, their workshop, their marriage bed, their grave, are one and the same spot. Hence they are, far more than animals, creatures of their environment. In a sense they are a living incorporation of their environment and cannot be understood unless the environment is understood also.

A tree is composed of a root system, a central stem or trunk, a series of ramifying and graduated limbs, branches, and twigs, a canopy of leaves, and reproductive parts which form, or assist in the formation of, fruits and seeds.

ROOTS

The root system serves two purposes: to support the tree in position and to take in water and dissolved minerals needed for growth. Roots divide and ramify like limbs; just as the leaves are found most abundantly at or near twig tips, so the tiny root hairs are most abundantly found at the root tips. The large muscular roots occurring near the base of the tree serve mainly as conveyors and as anchors, while the rootlets and the fine root hairs (in function like the villi of the human intestines) provide the actual contact between the tree and the soil. (That is why when a tree is being transplanted, the root hairs should not be allowed to dry out. If they do, the tree will remain dormant until it develops new ones.) Through these millions of root hairs many hundreds of barrels of water are daily absorbed out of the ground and conveyed—by some mechanism not yet thoroughly understood—up through the trunk and out to the very tip of the farthermost twig, part there to be used by the leaf in its fabrication of food and part to be transpired into the air. Unbelievable as it seems, more water is evaporated over a square mile of forest than over a square mile of ocean. (Think for a moment of the overlapping arrangement of leaves and their thousands and thousands of surfaces.) Through these same rootlets, dissolved minerals pass into the body of the tree to participate in its wonderful chemistry, but in quantities so small that the largest tree when burnt yields only a very small pile of ashes.

In general the root system of a tree corresponds with the branch spread, so that as far as the branches go, so go the roots. In many cases, however, they go farther, freed by lying in the soil of the mechanical difficulty of a limb in supporting great weight from a distant fulcrum. In no cases do the roots go as deep as the limbs go high.[2] A vertical section of an entire tree would reveal below ground a kind of foreshortened duplication of the limb structure above it.

As different kinds of trees do not have the same branch pattern, neither do they have the same root patterns. Some trees, like the pecan, have a long taproot that goes almost straight down for a considerable distance, in addition to a certain number of lateral roots. Other trees, like the elms, have lateral roots only, extending very widely in all directions. Still others, like the hackberry, may or may not have a taproot, according to the kind of soil they grow in. According to their root structure some trees are very easily uprooted, toppling over in every high wind; others cannot be pushed over by bulldozers. In all cases, however, whether a tree has a taproot or not and whether its anchor roots are deep or shallow, the majority of its feeder roots are to be found within a foot or foot and a half of the surface, for it is here that the soil is the richest and the ventilation the greatest. (This explains why when a tree is artificially fertilized, the fertilizer is placed in holes made at a depth of about a foot or a foot and a half, not at a depth of four, five, or six feet, nor merely spread about the surface.)

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[2] Except in the case of certain desert trees, as the mesquite and the sweet acacia, where, iceberg-like, there is more tree underground than aboveground.

In addition to food and water, roots must have air. A tree that grows up in a certain locality has its roots adapted from infancy to that particular kind of soil and to the amount of air and water there available. When the soil level covering the roots is changed—either increased or decreased—the tree suffers; if the change is too abrupt, it dies. Great harm is often done to trees where houses are being built by filling in dirt around them in an attempt to change the contour of the land. Unfortunately, the kind of fill used in such cases is usually the kind dug out to make basement excavations—a heavy, clayey, non-porous soil through which neither air nor water can pass—the very worst kind possible. Tree roots thus covered are literally suffocated, the tree's slow decline and eventual death is the inevitable result, unless the tree is young and vigorous enough to develop new roots near the new surface. The case is known of a California redwood that after being covered with 40 feet of fill managed to develop a whole new set of roots near the surface; the new roots and the remains of the old ones were discovered by excavation incidental to building a road skirting the tree. Such cases, however, are exceptions, few trees having the regenerative vigor of a redwood.

Roots are important as soil binders and soil conditioners. Their fine network is the primary factor in preventing wind and water erosion, which unchecked would in a few years make the earth one vast desert. The roots hold the soil; the cast-off leaves from above enrich it and mulch it. The roots also work incessantly to change the soil as well as to bind it. Mechanically they split rocks, forcing themselves into the tiniest crevice, then expanding with resistless pressure. Chemically they break down the soil, enzymes that are produced by the growing tips dissolving fragments of the hardest rocks as stomach enzymes break down the fibers of the toughest meat.[3]

Another kind of root is exemplified by the aerial roots of the banyan-tree of India and various other tropical species of *Ficus* or fig, such as the *higuerones* of Mexico. On these trees adventitious roots develop from the trunk or from the limbs, grow downward until they make contact with the ground, then thicken to form post-like supports that enable the tree to extend itself over very wide areas. Some of the Indian trees are said to cover acres, a single tree being composed of a multiplicity of trunks, each of which began as a slender aerial root. Similar aerial roots, on a much smaller scale, may sometimes be observed on temperate-zone trees. For example, the hackberry not infrequently develops adventitious roots that grow downward through the tree's own decaying center. Such roots sometimes develop to the degree that they split the weakened parent tree apart. The writer has a photograph of one such hackberry from which a root grew down through the trunk's central cavity, established itself in the ground, and stiffened and enlarged so much that it came to replace the rotting trunk as the tree's means of support.

Other trees may develop adventitious roots when their environment is accidentally changed. The limbs of some kinds of trees, such as the willows, will sprout roots if covered by soil; other trees grow roots from the trunk, as already pointed out, when covered by fill. On the other hand, the roots of some trees are capable of producing twigs and leaves if accidentally exposed to the air: this may be seen when overturned trees, with half of their roots sticking up into the air, develop lusty leaf sprouts from the former roots.

The roots become active in the spring several weeks before the upper part of the tree shows signs of life. If it were not for their initiating activities, the leaves could not develop nor new twig growth appear. On the other hand, they could not thus function if it were not for the quantities of reserve food stored in their tissues. Like a prudent merchant, a tree always manages to keep a certain amount of reserve food ahead against any possible emergency, storing nourishment in its ample bulk as a camel stores it in his hump. Even the seed consists of a minute embryo and two comparatively immense cotyledons, providing large amounts of prefabricated food until the seedling can establish itself and produce on its own account.

TRUNK

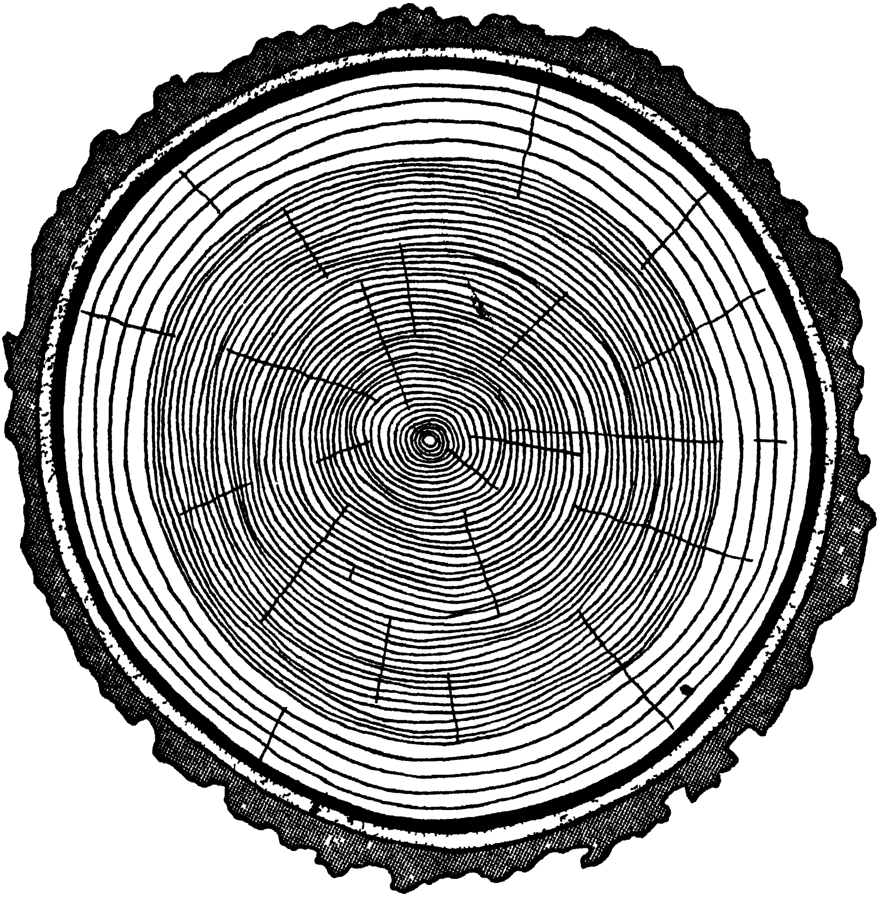
At first sight the stem, or trunk, of a tree would seem less complicated than its root system, 'being merely a post to hold the top in the air, or a connecting link between roots and branches. Actually, however, its structure is as complex as that of any other part of the tree, as we shall presently see, its apparent simplicity being the result of nature's economy of effort, compressing into the smallest possible space and the simplest form a variety of functions.

To begin with, we might ask why the trunk is round (that is, cylindrical) instead of square, rectangular, ovate, triangular, or any other shape. A forest of I-beams or two-by-fours or conical trunks is quite within the realm of possibility. Why, then, has nature been so obsessed with the cylinder? Why are all tree trunks, all limbs, and nearly all twigs cylindrical rather than quadrilateral or something else? Nature, master engineer and master geometrician, is not likely to have made a mistake and to have perpetuated that mistake some 100,000,000 years.

The advantages of the cylinder are many. In the first place, it contains more volume in proportion to its outer dimensions than any other known form; that is why we (imitating the tree trunk) make hot air pipes, steam pipes, natural gas pipe lines, and all other structures intended for the conveyance of liquids or gases, cylindrical.

Secondly, for sustaining weight the upright cylinder is the most efficient structure known; that is why in building we make so much use of pillars, columns, shafts, and cylindrical underpinnings. In young trees and in shrubs and flowering plants the strongest elements of the stem are distributed evenly around or near the outside, while the interior remains pithy or in some cases hollow. No other arrangement of a given amount of material could make the stem so strong; the same amount of material recast into a solid rod or a solid or hollow prism would be unable to sustain the same amount of weight. Old trees, whose heartwood may have rotted out entirely, are still capable of supporting an enormously heavy superstructure because of the fact that the remaining sound tissue is arranged in the form of a hollow cylinder.

In the third place, the cylindrical form gives the tree a certain



CROSS SECTION OF TREE TRUNK Outer bark, inner bark, represented by the dotted ring, cambium layer, greatly exaggerated in width, annual growth rings, in concentric circles from cambium to pith, sapwood, the outer section of the wood, heartwood, the older, more concentrated growth, pith, at the very center (shown here though not usually present in a mature trunk)

advantage against mechanical injuries to the bark. Since the vital parts of the trunk—the phloem and the cambium—are arranged in a ring near the circumference, destruction of this layer by complete girdling means death to the tree. Although at first sight it may not be apparent, this vital region would be more easily destroyed by animals rubbing against it or chewing on it or by various forms of human abuse if the shape of the trunk were quadrilateral, triangular, or anything else but round. A heavy animal rubbing against a flat side would almost certainly destroy the tender tissues along that whole side, on a young or thin-barked tree; four such operations would kill the tree were it quadrilaterally trunked. Any blow falling on a straight side is likely to extend itself across the entire area. On the other hand, any blow falling on a curved surface will strike it tangentially, affecting only a small part of the whole. Any one knows it is easier to saw or plane a straight surface than a curved one. To girdle a round trunk demands a conscious effort. The fact that certain rodents accomplish it is merely the exception that makes the rule more striking. Many men who set out deliberately to girdle trees often defeat their own ends by leaving part of the circle uncut, for a single continuous *verticle* strip of the inner bark, even though only one inch wide, can sustain life while new growth repairs the damage.

The trunk is composed of outer bark, inner bark (phloem), cambium tissue, sapwood and heartwood (xylem), and vascular rays, each part having a definite and distinct function.

OUTER BARK

Of these parts the outer bark is the least important, being largely dead tissue, cracked and molded into characteristic forms by the pressure of the constantly expanding trunk. The outer bark serves as a kind of buffer between the interior parts of the trunk and the outside world. Often thick, sometimes corky, it partly protects the trunk from mechanical injuries, from the teeth and claws of animals, and from insect damage. It also protects the tender inner bark and cambium from drying out, from the direct rays of the sun, and, to a certain extent, from cold. As it weathers off or is worn off on the outside, it is constantly replenished on the inside by the activity of the cork cambium, a layer of embryonic cells between outer and inner bark. On some trees, as the sycamore, the eucalyptus, and the madrone, the outer bark does not long remain attached to the trunk, falling off in shreds or tube-like sections (although in older trees a clearly marked section of outer bark builds up along the lower part of the trunk). The trunks of such trees are slick and smooth, white on the sycamore, creamish on the eucalyptus, a beautiful pink on the madrone. On the majority of trees, however, the outer bark forms into very characteristic furrows, ridges, bosses, or excrescences, that serve as one of the chief means of identification. The trunks of some trees are studded with thorns, as an additional protection. The bark of the redwoods is very thick, as much as two feet on some specimens, and is surprisingly fire-resistant, by virtue of which many of the giant trees have survived countless forest fires throughout the centuries. In the bark furrows and fissures of all trees many insect dramas take place. There insects hunt and are hunted, eat and are eaten; hatch, mate, die; rest, sleep, grow, spin cocoons, hibernate. The hunting wasp finds the deep furrows of the live oak a favorite hunting ground. The ichneumon fly drills through two inches of bark and wood to deposit its eggs in the burrows of the sawfly larvae. The cicada leaves its shed skin on tree trunks in many parts of the world.

INNER BARK

The inner bark, or phloem, together with the cambium layer that gives rise to it, may be considered the most important part of the trunk, since when a small band of it extending completely around the trunk is cut away, the tree dies. Every other part of the trunk may be damaged without killing the tree: the outer bark may be scraped off, the heartwood chiselled out, even the sapwood riddled; but once a thin encircling strip of phloem is destroyed, the tree is doomed.

The phloem must be continuous from the roots to the crown; it is the vital link between top and bottom. In importance it is roughly equal to the aorta, jugular vein or spinal cord of the animal body. It is the highway along which travels the food that is fabricated in the leaves. When it is severed or obstructed, death comes to the tree not from the top down but from the roots up. A tree girdled a foot above the ground, for example, remains unaffected, at first, above that point. Leaves, twigs, branches, and the trunk itself continue in perfect health. The roots continue to draw up water, the sapwood conveys it to the leaves, the leaves manufacture the needed food, and the phloem carries the food downward to nourish all parts of the plant body—downward to within one foot of the ground, where, the road being cut away, it can go no farther and hence accumulates as a bulge just above the cut region.[4] From the cut down, no food is received. The root system struggles on, drawing on its reserves, as long as it can—for a year usually, rarely for two years; then suddenly it dies—dead of starvation in the midst of abundance. Still connected structurally with a healthy top, it is cut off from receiving the produce of that top. When the roots go, the thriving top goes too, killed not by starvation but by lack of water, which can be supplied by the living roots alone.

Such is the strange history of a girdled tree, which many people expect to die a few days after the girdling has taken place but which does not do so for the reasons just explained. Oddly, a girdled tree frequently produces its most abundant fruit crop the season before it dies, which is Nature's supreme effort to reproduce the species when the individual is doomed. Oddly, also, the phloem may be destroyed along one-half, two-thirds, or nine-tenths of the trunk without causing death to the tree if this damage leaves uninterrupted one continuous strip of vertical phloem running from the roots to the crown. This strip may go straight upward or it may twist and snake its way up the trunk; the essential thing is that it be continuous, for through it, as through anastomosing veins, the whole life of the tree may temporarily pass, and from it new phloem may grow outward to clothe the tree eventually with an entirely new bark structure.

In thickness, the phloem occupies a relatively small part of the total trunk diameter, a tree two feet in diameter having a phloem layer of one-half, three-quarters, or an inch thickness, according to the species. As the tree grows the phloem layer naturally increases in thickness, although the increase is slight when compared to the great increase of sapwood and heartwood. On the other hand, even though the phloem layer is comparatively thin, its total volume is larger than it seems, since it is always spread out along the rim of the cylinder.

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[4] What really happens is that the food carried downward stimulates cell growth above the girdling with an increase in diameter which contrasts with the stationary diameter below the girdling.

Most trees are dicotyledons[5] and have the phloem on the outside of the cambium layer; such trees are thus enabled to expand continually in girth—indeed, must do so as long as they live. On the other hand, the monocotyledons,[6] as represented by the palms, are so constructed that their phloem and xylem tissues are arranged in special bundles scattered throughout the stem. These trees have no cambium layer and no continually expanding phloem layer around their periphery; hence they do not grow in girth after reaching a certain size. Also, since they have no phloem layer, they cannot be destroyed by girdling. A palm trunk may be ringed like a table leg turned on a lathe, yet it will continue to live so long as any part of the trunk is left intact.

The bark of the dicotyledons has a number of interesting uses. It is often eaten by animals, particularly during protracted snows when no other food is available. The bark of the birch was used to make Indian canoes. The bark of some kinds of oak is our source of cork; the bark of other oaks gives us tannin. Bark of the paper mulberry is used by the Chinese in the preparation of high quality paper and by the Polynesians to make mats and articles of clothing. Some of our first writing tablets were made of bark; indeed some etymologists have sought to connect the word *book* (cf. German *Buch*, plural *Bucher*) with the word *beech* for this very reason. The very thick bark of the redwood, which formerly was treated as a nuisance because it interfered with sawing operations, is now utilized in the manufacture of various kinds of fibrous products.

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[5] "Dicotyledons, characterized by an embryo which has two cotyledons. The parts of the flowers of most species are in twos, fours or fives. The leaves of most species have a network of veins. A cambium is usually present, and the vascular tissues of the stem are arranged in a cylinder." Robbins and Rickett, *Botany*

CAMBIUM

The cambium layer (from Latin "exchange") is a layer of actively dividing cells theoretically only one cell thick arranged as a continuous cylinder near the outside of the trunk between the phloem (inner bark) and the xylem (sapwood). This is the part of the stem that does the growing, and its ingenious location between phloem and xylem is the fact that enables the trunk of dicotyledons to increase continuously and indefinitely in girth. During the season of growth, cells in the cambium layer are in a state of continuous division and multiplication. Of the new cells formed, those on the outside come to form new phloem tissue; those on the inside new xylem tissue. Thus the cambium layer itself remains always at the same thickness while being steadily pushed outward, together with the inner bark, by the new tissues of sapwood forming on the inside. In a young tree, for example, one inch in diameter, the cambium layer lies just under the bark, one-half inch from the center of the tree; in an old tree ten feet in diameter the cambium layer still lies just under the inner bark, but both it and the bark are now five feet from the center of the tree.

Growth in diameter, then, is accomplished by the laying down of successive layers of sapwood, while the embryonic cambium and the elastic phloem travel ever outward. (Not elastic in the sense of a rubber band that stretches without increasing its substance, but elastic like the bony structure of a child's head that increases in size by growth while maintaining its proportions.) Every layer of sapwood was once cambium. Growth starts in the center of the tree and spreads outward radially, just as a pebble dropped in a pond produces ripples in all directions. The imagined solidification of these ripples furnishes a good example of what occurs in the tree. Each ripple is a new layer of sapwood, each layer has its crest and its trough; the ripples continue in ever-widening circles until the force of the original impulse is dissipated or until they encounter the edge of the pond. The energy contained in the fall of the pebble represents the original growth impulse, while the edge of the pond represents the limitations imposed by environment.

The healing of pruning cuts, bark wounds, and cavities is made possible by the cambium layer, which forms callus tissue over the exposed region, growing from all sides toward the center. Callus tissue that forms over a cement filling, for example, is composed of xylem and phloem with the embryonic cambium between the two; each year that passes adds a new layer of sapwood to the callus, so that, if the tree lives long enough, the cement may come to be covered by 4, 5, 6, or more inches of good, sound sapwood. Since the monocotyledons (as explained above) have their xylem, phloem, and cambium located in fibrovascular bundles scattered throughout the stem instead of being arranged according to the ingenious plan of the dicotyledons, they cannot expand continuously in girth nor can they heal over their wounds. A palm tree never forms callus tissue. Wounds on the trunk remain open throughout the life of the tree. They may be filled with cement plugs or treated with antiseptic and waterproof paints, but they will never callus over. Although most organisms, both plant and animal, have the power of healing their wounds, so stately and beautiful a thing as a palm tree has no regenerative tissue in its trunk; once damaged it is as powerless as a post to repair itself.

SAPWOOD

The sapwood of the trunk, together with the heartwood, which was formerly sapwood, is the wood proper. It is the most familiar part of the tree, being that which we burn in our stoves, make our houses of, pin up our clothes with, and turn into baseball bats, tennis rackets, and golf clubs. It constitutes the main substance of the tree, giving it body, rigidity, and hardness. In young trees it forms practically the whole trunk, and even on old trees it forms half or more of the trunk as well as virtually all the body of the limbs, branches, and twigs.

The function of the sapwood, apart from giving the tree rigidity, is that of conveying water and dissolved ingredients of the soil up from the ground to the leaves, where they are used in the manufacture of food. At the same time it supplies water to all tissues of the organism, which, being composed of cells, need water quite as much as the cells of the animal body. Microscopic examination of the sapwood shows it to be composed of relatively long tubular cells arranged vertically end to end, like sections of pipe forming a pipe line. The thickened cell walls give the tissues their woody strength, while the large open interiors with the sieve-like ends make possible the rapid passage of water through the system. The very name *sapwood* indicates the function of this part as a conveyor of fluids: its tissues are at all times replete with water or sap (modified water), even during the dormant period when, according to popular belief, "the sap is down"—imagined by many to have fled to the roots. Actually the wood is as juicy in the wintertime as in the summer or spring, as anyone who has ever sunk an axe into it knows.

When a tree dies, it is the evaporation of water from its tissues that makes the sapwood become hard and dry instead of soft and juicy. The evaporation of water also explains the loss of weight that dry wood shows over green wood. Those trees whose pores (sapwood vessels) are very large, such as the chinaberry, the willow, the tree of heaven, lose much more weight in drying than those trees whose pores are small, such as the white oaks, the mesquite, the ebony. In other words, trees which are largely water to start with become almost substanceless when dry, while slow-growing kinds with fine, close pores lose comparatively little weight when dried and, consequently, in general warp little. (The mesquite, for example, warps and shrinks in drying as little as any known wood, being for this reason excellent material for levels, gun stocks, furniture, etc.) Among the oaks two great groups —the red oaks and the white oaks—are distinguished by lumbermen according to the size of their pores, the former having large open pores and the latter fine closed ones. Through a two-inch block of sapwood of some of the red oaks smoke may be blown. The pores of some woods are large enough to be distinguished by the naked eye. In some the point of a pin may be inserted.

In the temperate zones where a tree grows only during spring and summer the sapwood is formed according to a definite pattern. During the spring when growth is most rapid the sapwood has large cells; during the summer when growth is tapering off the cells become increasingly smaller. The regular juxtaposition of spring and summer growth constitutes a pattern easily distinguished: it is called a ring and represents one year's growth. Counting the rings from the center of the trunk outward tells the age of the tree—one ring for each year. Counting the rings in a limb tells the age of that limb but not necessarily of the tree, for the limb may have appeared after the trunk had developed. Rings near the center are the largest, since trees grow fastest when young; rings toward the outside get smaller and smaller (other factors being constant) as the tree gets older. Rings vary in thickness from a barely perceptible line in some of the slow-growing trees to half an inch or more in the swifter trees. The size of a ring represents only half of the trunk's growth. A ring half an inch wide, for example, means that the trunk increased one inch in diameter that year. Sometimes the center of the rings is not in the geometric center of the trunk, indicating that for environmental reasons more sapwood formed on one side than on the other. In such cases the ring is curiously shaped: almost flat at some spots, flaring out suddenly at others, forming an ellipse or irregular curve rather than a circle. In a forest of straight-trunked pines, on the other hand, where environmental pressure is even on all sides, the rings are of a nearly uniform width all the way around and describe a nearly perfect circle.

Since trees grow more in wet years than in dry years, the widest rings indicate wet years, the narrowest rings dry years. This simple fact is the basis of a new science—dendrochronology: the science of studying weather and climate in relation to the growth of trees. For example, if you cut down a tree in Oregon in 1950 and count backward (from the outside toward the center) 25 rings and find a series of six or seven unusually narrow rings beginning at that point, you may conclude that from 1918 to 1925 Oregon experienced a period of drouth. If you then cut down numerous other specimens in different parts of the state and find them telling the same story, you may be sure of it. If to continue the investigation you cut down trees in Washington, California, Nevada, Wyoming, and Montana and find the same evidence there, you will know that the drouth was general over the Northwest.

Applications of this discovery on a grand scale are obvious. Sapwood specimens[7] from trees all over the world can be compared to give continuous climatological readings running back 2000 years and more. For this purpose the longest-lived trees—the redwoods, sequoias, firs, cypresses, are of greatest value, although even petrified trees or nearly petrified ones have been used to fill in the gaps. The sapwood rings constitute a great natural calendar, providing data of the highest value that may be correlated with other natural phenomena, such as the formation of new lakes or the drying up of old ones, the deposition of silt in the great delta regions, the amount of wind and water erosion over given regions, etc., to help reconstruct the world's past climate. Climatological charts based on the testimony of the tree rings reveal the cyclic nature of climate and so form corroboration of Ellsworth Huntington's theory of Climatic Pulsation.

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[7] It is no longer necessary to cut down a tree in order to count its rings. Sapwood and heartwood specimens may be cut out of a living tree by a special drill that pulls out an intact cylinder, somewhat like plugging a watermelon.

In the tropics where seasons are wet and dry rather than hot and cold the tree rings do not offer the same facility for study, since one ring does not necessarily indicate one year. In some regions growth is practically continuous with no rings at all forming; on other trees and in other regions several rings may form in one year, depending on the frequency of the rainy spells.

The sapwood has a number of enemies, possibly the commonest being the borers that riddle it with their labyrinthine tunnels, eating the wood as they go along. Borers in the sapwood of cut mesquite are so numerous that a few feet away from a pile of logs their chewing may be heard like rain on the roof. Cases are on record of borers emerging out of wood (mesquite, cherry, walnut) ten or fifteen years after it has been made into furniture.

Although the heartwood of most trees is considered more valuable for lumber and furniture, the sapwood is also very commonly used, either alone or in combination with heartwood. Pine, for example, is nearly always pure sapwood. When a piece of lumber is so cut that it is part sapwood and part heartwood, it is harder to dry, since the sapwood contains much more water. Such differential drying is often responsible for warping, shrinking and cracking.

HEARTWOOD

The heartwood of the trunk is former sapwood that has ceased to function in the conveyance of fluids. Young trees have no heartwood, being all sapwood, cambium, and bark. As a tree gets older and larger, the sapwood in the center gradually loses its function, drying out and hardening, becoming heartwood. As new layers of sapwood are added on the outside, the oldest layers of sapwood on the inside become heartwood. A certain proportion between sapwood and heartwood comes to exist, the proportion being different for each kind of tree and also being influenced by age and rapidity of growth. Some trees, such as the hackberry, never form heartwood. Others form it very slowly, like the persimmon, which needs 100 years to begin producing it; others form it within the first few years of life.

Heartwood is harder than sapwood, denser, drier, and of a different color, generally darker. Where the sapwood is almost always white, creamish, or light brown, the heartwood is usually black, dark brown, bronze, or red. The combination of sapwood and heartwood in a piece of lumber often produces a very pleasing effect —the original two-tone. The heartwood of some trees is extraordinarily beautiful and almost fabulously valuable; for example, the satiny heart of mahogany, the rich warm heart of walnut, the glistening black heart of ebony, the deep rich redness of mesquite heart, the rose-colored *huisache* heart. Some heartwoods are amazingly hard, that of the *quebracho* defying the axe and that of the Mexican ebony (*Pithecellobium,* or *Ebenopsis, flexicaule*) as resistant to nails as an iron post.

Heartwood forms in limbs as well as in the trunk, the larger the limb the greater the heartwood. Instead of heartwood, the center of many limbs, particularly the smallest ones, on some trees is composed of pith.

Although the heartwood has no physiological function, it is useful to the tree for support, serving like reinforcing rods in a post of concrete. Without their strong heartwood some of the larger trees would be unable to resist wind storms or bear even the weight of their own limbs. Whenever limbs or trunks break off in high winds, the cause is usually decay of the heartwood. For strong and tough as the heartwood is, it is susceptible to attack by a number of wood-rotting fungi. In fact, the heartwood, where exposed, decays much more rapidly than the sapwood (except when both are dead, and then the sapwood decays first). The very

Plate 1. A live oak tree displays its pattern of branches against the sky.

Plate 2. TREE TRUNKS, BUTTRESSES, AND ROOTS. On the tropical fig of Mexico (*upper left*) as on the more northern arborvitae (*lower left*), buttresses support the enormous superstructure. Although its trunk is partly destroyed, the palm tree (*upper right*), a monocotyledon, lives because its fibrovascular bundles are scattered. A dicotyledon, with bundles in a ring, could not survive this injury. *Lower right:* Tree roots may extend as far as the spread of the branches.

strong heartwood of oak that breaks teeth out of the sharpest saw and mocks at the axe and the wedge is quickly reduced to a pulpy, soggy mass by the strengthless filaments of the bracket fungi of different kinds. Heart rot in forests causes the annual loss of millions of dollars' worth of timber. This is the reason why correct pruning, which prevents cavity formation, and correct cavity treatment, which repairs existing cavities, are both so important.

What is called grain in wood is the heartwood and sapwood rings and the vascular rays seen from different angles according as the planks are cut out. When a log is crosscut—that is, sawed perpendicularly to its length—the rings are seen in their entirety—a series of concentric circles. When a log is cut lengthwise, the rings and rays appear in various interesting patterns, varying according to the distance of the plank from the center, only a small arc of each ring being visible but the whole length of the rays. When a log is quarter-sawed, only those planks are cut that run out radially from the center of the log to the circumference, like the spokes of a wheel. Since this method shows up the beauty of the grain to greatest advantage, it is often practiced with some of the finer woods, however, since fewer pieces can be cut from a given log, it is too wasteful to be generally employed.

VASCULAR RAYS

The vascular (once called medullary) rays, seen as tiny lines running perpendicularly to the rings, are channels by which food and water are transported radially throughout stem, limbs, and branches. Food traveling down the phloem, which may be roughly compared to the arterial system of the animal body, must reach every cell of the sapwood, doing so by means of the vascular rays, which thus may be compared to the capillaries. When wood is split, it opens along its vascular rays.

LENTICELS

Lenticels are respiratory pores that occur scattered over the surface of trunk, limbs, branches, and twigs. On most trunks they are almost invisible, hidden away among the furrows and scales of the coarse outer bark. On other trees they are quite noticeable; on the Siberian elm (*Ulmus pumila*), for example, they appear as tiny, raised, rust-colored islands, occurring in such numbers as to give the trunk its characteristic reddish look. They are avenues for entrance of air into the trunk and branches, just as stomata admit air to the leaves. Whenever a trunk becomes too heavily covered with lichen, moss, or vine, the function of its lenticels may be interfered with.

In company with roots and twigs, the stem or trunk also serves for the storage of manufactured food. The rush of spring activity, including the unfolding and enlargement of the leaves, twig growth, and in some cases formation of flowers and even seeds, before the leaves have started to function, could not occur if it were not for the large amounts of food stored in the various parts of the tree.

SUPERSTRUCTURE

The upper end of the trunk gives rise to limbs, branches, and twigs. Where the trunk ends and the branches begin is a point not always easy to determine, for sometimes branches appear along nearly the whole length of the trunk, while this, mast-like, continues straight upward; sometimes the trunk yields a tuft of branches at the very top; and sometimes it divides and subdivides in such a manner that its existence gradually merges with that of the limbs. Each kind of tree has its characteristic manner of branching; however, individual trees may depart from the standard form of their species, in accordance with environmental peculiarities.

Based upon their manner of branching, trunks are divided into two kinds: *deliquescent* (*decurrent*), and *excurrent*. The deliquescent form is that which crotches repeatedly, making a gradual transition from trunk to twig, illustrated by the oaks, the elms, the walnuts, and many others. The excurrent form is that which grows like a mast, throwing out branches more or less evenly on all sides but carrying its tip up to the very top. This type is represented by the pines, the firs, the spruces, the junipers, and nearly all the conifers, which, because of their straight growth and little taper, people the ocean with masts and the land with telephone poles, in addition to providing the bulk of the world's

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lumber. Most excurrent trees have a conical, Christmas-tree-like shape, as have the various red cedars (*Juniperus*) and the ornamental spruces. Some of them, however, habitually have other shapes: some of the pines have obdeltoid or irregular shapes; many of the conifers gradually change their shape with age.

Some kinds of trees represent a sort of compromise between the two forms, being sometimes deliquescent, sometimes excurrent, other times being, or trying to be, both at once. The sycamore and the cottonwood, or poplar, are good examples. Although the sycamore may be considered predominantly excurrent, it is often found with divided bole, each part of which grows excurrently as if it were a single tree. The cottonwood exists in so many species and varieties that it is hard to generalize about it. Often excurrent, it is as frequently deliquescent, being perhaps the most noticeable borderline case of all.

Some trees, like the papayas, the palms, and certain other tropical and semi-tropical trees, have no branches at all, putting out instead from the embryonic tip a series of huge leaves on greatly enlarged petioles. Some of the palm leaves are as large as a table top and some of their saw-edged petioles 10, 12, or 15 feet in length. These, although they simulate branches, do not function as branches, dying back to the trunk and falling off just as dicotyledonous leaves fall from the twig, so that growth continues only in an upward sense, never outward, and a palm 20 years old extends sideways just as far as a palm 100 years old.

The silhouette formed by each kind of tree according to the structure and arrangement of its branches, is characteristic for each species, serving to identify the tree at a distance, both when in leaf and when bare, as surely as the shape of the leaves identifies it at close hand. And just as the different leaf shapes have specific names, so the different silhouettes have their names. Thus a tree may be conical, like a spruce; cylindrical, like the Texas elm; rounded, like the live oak; spreading, like the walnut; obdeltoid, like the American elm; triangular, like some of the pines; irregular, like the hackberry; pointed (fastigiate), like the Lombardy poplar or the Italian cypress; drooping, like the weeping willow; and so on. The tree in winter, stripped of leaves, flowers, and fruit, may be considered the plant skeleton. Although pruning may change the shape of a tree temporarily, the pruned tree will always tend to revert to its natural form. Even removal of the whole crown (topping) is unable to deform a tree permanently, for the new growth will tend to reshape the tree along the original lines.

The main framework or scaffolding of a tree is composed of limbs; the limbs give rise to branches; and the branches to twigs, the smallest woody element. The limbs, branches, and twigs conjointly are called the crown. The transition from trunk to twig is usually a very gradual one, passing from larger to smaller limbs and larger to smaller branches in an orderly sequence. In some cases, however, twigs appear abruptly from the trunk or the main limbs; these adventitious twigs are called "suckers" or "watersprouts" and should be removed as often as they appear, in order to divert growth to the upper and outer parts of the crown. The appearance of numerous watersprouts often indicates that a tree is dying at the top, although some kinds of healthy trees normally produce them. Adventitious twigs also appear along trunk and limbs of any tree that has been topped or pollarded, developing in this case very rapidly into branches.

Twigs, branches, and limbs grow in length and in thickness as long as the tree lives. With the passage of time twigs become branches, branches become limbs, and limbs become larger limbs. Once the main outlines of a mature tree have been established, it would seem that it would no longer continue to grow. Indeed many people, misled by analogy with animals, believe just that: that only young trees grow, that old trees merely maintain their status quo. Actually (with the exception of monocotyledons, which grow only at the top) a tree continues to grow as long as it lives. It may grow at different rates, sometimes fast, sometimes slow, but it cannot stop growing, even though by continued growth it sometimes works its own destruction. Trees sometimes become so top heavy that they split apart, particularly when whipped by the wind or weighted by ice. Great limbs sometimes break off under their own weight, even on perfectly still days. The California valley oak is famous for this habit: on a day when no breath of wind is stirring a sound limb suddenly breaks off with a resounding crack and comes hurtling to the ground. This remarkable phenomenon represents the attempt of nature to prune the top-heavy crown;

unfortunately, however, such breakage nearly always leaves unhealed stubs or trunk wounds that open avenues of infection to the heart of the tree, eventually causing or hastening its death. The great problem facing every tree is how to support a constantly larger and heavier superstructure from a central axis—an increasing weight which even the strongest and toughest woods cannot withstand indefinitely. If a tree could evolve some method of solving this mechanical problem[8] and if the soil around its roots never became exhausted and if its water supply were never impaired, it could well live forever.

LEAVES

Perhaps the most interesting and wonderful parts of the whole tree are the leaves. These are its flesh, as the limbs and branches are its skeleton. Leaves clothe the tree, giving it form, color, movement, life. They provide shade, adornment, beauty. They shelter the birds, shade and protect the animals, embellish the countryside. They interpose a barrier of green coolness between the sun and the ground, thus making possible human and animal existence in places where it would be otherwise impossible. They transpire great quantities of water into the air, humidifying and freshening it. By lowering the temperature of the ground underneath, they create minor ascending and descending air currents. When they die and fall to the ground, their bodies decompose, enriching and mulching the soil.

More than all this, the leaves produce food for the tree, and hence for all other forms of life dependent directly or indirectly on the tree. Indeed, this is their primary function; all other uses are secondary and incidental. Every leaf is a busy factory, the most marvelous factory in the world, whose motive power is the sun's rays and whose end-product is food. The green leaf—that of trees and other plants—is the only source of food on our planet. It is the bridge between the organic and the inorganic worlds. Only the green leaf is capable of manufacturing organic food out of inorganic elements. *No other power, natural or artificial, can ac-*

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[8] The banyan-tree of India and other tropical figs have virtually done so. See the discussion in the section on roots.

complish this miracle. There are other ways by which food may be stored, transported, transformed, but only the green leaf can *manufacture* it. Hence all other life, animal and human and non-chlorophyll-bearing plant life, is dependent on the green leaf. Man, animals, insects, and plants without chlorophyll are all parasites in the sense that they cannot manufacture their own food. Men derive their food from plants or animals or both. Carnivorous animals derive theirs from herbivorous animals, which derive theirs from plants. If green plants disappeared from our planet tomorrow, all other forms of life—saprophytes, parasites, vertebrate, invertebrate, fish, fowl, insect, quadruped, man himself—would disappear shortly thereafter. We cannot exist without green plants; on the other hand, they can exist very well without us.

Not only does all our food come from the green leaf but the bulk of the energy we use to do the world's work comes from it as well. For it is by the activity of the green leaf that the tissues of the tree are builded, and it is the body of the tree burned as wood and coal that furnishes power to run our machines. The energy of the sun's rays, transformed by the green leaf into a form utilizable, storable, and controllable, is the ultimate source of our energy. Only atomic power, by duplicating the sun's energy, provides us with the means of bypassing the green leaf.

The process by which the leaf manufactures organic food out of inorganic elements is called *photosynthesis*, which is the Greek way of saying "production-by-light." The raw materials used are carbon dioxide and water—the first taken in from the air by the leaves, the second absorbed from the ground by the roots and sent up through the sapwood to the leaves. When these two elements are brought together in the green leaf, the action of the sun's rays enables it or activates it to combine them and transform them into two different compounds: pure oxygen and sugar (dextrose). Chemically the reaction is written thus:

$$6\,CO_2+6H_2O\rightarrow 6O_2+C_6\,H_{12}\,O_6$$

This is the most important chemical formula that exists on our planet, for both end-products of this reaction are indispensable for the sustenance of animal life—not only the sugar (which is later changed to other food products) but the oxygen as well. Animals and humans, by constantly using up oxygen and exhaling carbon dioxide in their respiration, would eventually vitiate the air to the point where they could no longer exist. Green plants, by reversing this process, that is, by using up carbon dioxide and emitting oxygen, maintain the percentage of both elements at approximately a uniform level and so make possible our existence.[9]

The mechanism by which photosynthesis is accomplished is still imperfectly understood. It occurs in *green* plants exposed to the sun directly or by reflection. Green plants are those which contain chlorophyll. Plants that are not green, such as mushrooms or bacteria, have no chlorophyll and thus must grow saprophytically or parasitically upon green plants.

In spite of their great diversity of size and shape, all leaves consist of essentially the same parts: a petiole or stem (sometimes absent) and a blade, a thin, flat sheet constructed and extended in such a manner as to receive as much sunlight as possible. The blade consists of (1) a waxy covering or *cuticle*; (2) a single layer of cells called *epidermis* (cuticle and epidermis are on both the top and bottom); (3) a layer of large upright cells called the *palisade layer*, each cell of which contains tiny bodies called *chloroplasts* inside which is the vital chlorophyll; (4) a layer of irregularly shaped, loosely arranged cells forming the *spongy parenchyma;* (5) the veins that form the communication system. The large vein running down the leaf's center is called the midrib; the others are called lateral veins. Some leaves are pinnately veined (reproducing the design of a feather); some are palmately veined (having the major veins branching out radially from a common center); some are parallel-veined. (This last type is one of the distinguishing marks of the monocotyledons.)

On the lower surface of the blade there are thousands of tiny openings called *stomata,* each surrounded by two special *guard cells* that partially or completely close together at night and open during the day to allow gases from the atmosphere to enter and gases from the interior to escape. They also allow water to evaporate and by so doing make possible the entrance of more water through the roots. On a hot day when the sun is beaming down and all the stomata are open, a tree transpires great quantities of water, drawing it in through the roots and evaporating it through the leaves—as effective a mechanism as a fountain, if not as spectacular.

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[9] Plants also respire as animals do, using up oxygen and giving off carbon dioxide. However, the effect of their respiration in comparison with the effect of photosynthesis, the reverse process, is almost negligible. They produce far more oxygen than they consume.

It is through the stomata that many kinds of fungi gain entrance to the interior of the leaf, deforming or killing it by absorbing its substance. Once inside the leaf, certain kinds of disease-producing organisms have the power to travel through the veins into the twigs and hence through all parts of the tree. These diseases, called vascular diseases, are the most difficult of all to control, because they work from the inside. Although it may be difficult or impossible to eradicate such diseases once established, they may be prevented by periodic spraying (see chapter on spraying), the purpose of which is to coat the leaves with a protective layer of copper, or some other substance, through which the pathogenic fungi cannot pass.

In structure leaves are simple or compound. A simple leaf is one unserrated blade growing from a petiole (in sessile leaves directly from the twig). A compound leaf is a series of discrete blades (leaflets), all growing directly or indirectly from the same petiole and hence forming one unit. Leaves may be compound palmately, like those of the horse-chestnut wherein several leaflets spring radially from a common center, or compound pinnately, like those of the locust, wherein from a central stem (like the quill of a feather) paired leaflets grow out laterally. The compound leaf is usually larger than the simple leaf, although not necessarily so. The leaf of the banana is simple, while the leaf of the sweet acacia, or huisache (*Acacia farnesiana*), is compound, but the total leaf area of an average huisache tree, each leaflet of which is barely ⅛ of an inch long, would not equal the area of a single ten-foot banana leaf.

A common size of a simple leaf may be 4 or 5 inches long by 3 or 4 inches wide. Temperate-zone leaves are usually medium-sized, like those of the elm or the oak, whereas tropical leaves tend to be either very small or very large. The leaflets of the mesquite and the huisache, small as they are in Texas, get progressively smaller as one goes south into drier, hotter Mexico. On the other hand the elephant ears, bananas, and water-lilies produce their immense leaves also under tropical skies, but within wet surroundings.

In shape leaves are so diverse that botanists have exhausted the resources of a dozen languages in an effort to describe them. They may be round, oblong, lance-shaped, sword-shaped, spindle-shaped, cross-shaped, egg-shaped, fan-shaped, and every other shape. No figure is too extravagant or too fantastic to be reproduced in a leaf form and hence reduced to beauty. Yet among all the many thousands of different kinds of trees no two have like leaves; although there may exist strong similarities, there are no duplications. Indeed among the uncounted billions and billions of leaves that exist or have existed or will exist there are no two identical, not even among those of the same kind, not even those of the same tree.

In color leaves are of course predominantly green, although on many ornamental plants they show streaks of yellow, white, pink, and red. The foliage on young trees is frequently all red; similarly the new growth on old trees is often red. New leaves on the mango-tree, for example, are always red, becoming green only several weeks after they have attained full size. The petiole and even midrib (sometimes also the lateral veins) on many well-known trees are reddish. The beautiful *madroño* is more red than green. The leaves of the eucalyptus are bluish-green; the leaves on young eucalyptus trees or those on new shoots on older trees, are definitely bluish. The leaves on many trees are whitish underneath. The leaves of the shrub Texas silverleaf (*Leucophyllum texanum*) are gray on both surfaces.

Leaves on many coniferous trees, such as juniper and cypress, are formed on a different pattern: tiny scales wrapped closely around a central axis, arranged overlappingly like shingles on a roof. Because of this arrangement and their small size, the leaves are not visible individually unless examined very closely; the number of these tiny leaves on a large tree is truly enormous. Other conifers, such as the pines, have leaves in the form of "needles"—long, thin, flat, tough structures, built to resist desiccation by cold and injury by snow. Different kinds of pines have different numbers of needles to a bundle, each bundle being enclosed by a slender sheath for a little distance along its base. Some pines have two needles to a bundle, some three, some five. The structure of the conifer leaf is extremely interesting, being found on the oldest, the largest, and the most widely distributed trees on earth (cypress, redwood, giant sequoia, fir, and pine).

Some kinds of trees are evergreen, never seeming to lose their leaves.[10] The evergreen impression is accomplished by the more or less constant appearance of new leaves so that with the death of old ones the tree is at no time bare. The foliage of many ornamental varieties of evergreens, such as arborvitae, which are trained to grow densely in bush-like shapes, gradually dies in the center as it grows at the edges. Not all the conifers are evergreen nor are all broad-leafed trees deciduous, although such is generally the case. The larches and bald cypresses are as deciduous as elm or maple, while the famous southern live oak (*Quercus virginiana*) is evergreen (hence its name), retaining its thick, leathery leaves throughout the severest weather, shedding them only in March, at the time when the year's new leaves are already forming.

When leaves begin to brown and fall off in the autumn, they do not do so of their own accord, there being nothing in the structure or mechanisms of the leaf to provide for its suicide. What happens is that the tree sheds its leaves by forming the so-called "abscission layer" at the juncture of petiole with twig, a layer of tissue that functions like the closing of a valve so that no more food or water reaches the leaf, and it dies. Thus the tree defends itself at a time when growing conditions are unfavorable: when the ground is frozen, the sky overcast, and the air too cold for the proper circulation of fluids. (A tree cannot warm itself by exercise.) In the tropics deciduous trees lose their leaves in the seasons of drouth; this is also for their own protection, for con-

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[10] The longevity of some leaves is surprising. The following list is from Molisch (Fulling) in *The Longevity of Plants*:

Pinus pinsapo	11-15 years
Taxus baccata	8-10 years
Abies nordmanniana	3- 5 years
Araucaria bidwilli	15 years
Laurus nobilis	4 years
Pittosporum tobira	3- 5 years
Ilex aquifolium	2- 4 years
Aucuba japonica	2- 3 years
Osmanthus aquifolium	5 years

tinued evaporation of water through the leaves when none or very little may be drawn up by the roots, would eventually cause the tree's death.

Leaves almost always appear at or near twig tips, these being the regions that contain the most embryonic tissue. On some tropical trees, however, such as the mango, leaves may occasionally grow directly from large limbs. On most temperate-zone, broad-leaved trees, leaves are developed only during the springtime,[11] no more new leaves appearing during the summer. However, if a tree is defoliated by insects or by mechanical means, it may produce new leaves from adventitious buds. A tree may be defoliated three times during the course of a summer and each time respond with new foliage, drawing on stored food, but with the fourth defoliation it dies.[12] In contrast to this system, many tropical trees, such as the yellow mombin (*Spondias mombin*), produce new leaves continuously throughout spring and summer from the continuously growing stem tips. Defoliation of such a tree could hardly occur, since, hydra-like, it forms new parts as rapidly as the old ones are destroyed.

Many leaves have bristles at their tips and along their margins, usually at the termination of the veins. Certain trees, such as the prickly ash, have prickles on the petiole and even on the midrib. The lower surface of many leaves is covered with *tomentum*: a dense mass of very fine "hairs" or processes which must constitute a veritable jungle for the tiny insect that attempts to make its way through them. In most cases the tomentum is soft and woolly and may be rolled up in little balls by the thumb. In some cases, however, the leaf surfaces are roughened rather than softened; the leaf of the anaqua (*Ehretia anacua*), is so rough that it will draw blood when rubbed sharply across the face or the back of the hand.

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[11] Notice the expression "leaves are *developed*." Leaves are actually *formed* (in miniature) during the preceding spring and summer and wrapped up snugly within the protective leaf buds. They remain on the tree in this form through late summer, fall, and winter, dormant like a chrysalis in its cocoon; in the spring they swell up, burst open the bud scales, and within a few days develop into full-sized leaves. At the same time *next season's* leaves and twigs are forming in miniature in their axils; and so the cycle goes on.

[12] One defoliation will kill spruces and other evergreen conifers.

Some leaves have glands or gland-like structures of unknown function. The leaf of the tree of heaven (*Ailanthus*), has two gland-like swellings at its base. The leaf of the eucalyptus has a curious vein running around its margin into which all lateral veins empty. Many compound leaves grow wings along the rachises (extension of the petiole from which the pinnae or leaflets arise).

Perhaps the most curious structures of all are the *pulvini*—enlargements at the base of the petiole by which movement is effected when a leaf is burnt, pinched, or sometimes only touched. The pulvini are small chambers or reservoirs which may be quickly emptied in response to stimuli; the resulting decrease in turgidity causes the leaf to droop, folding downward like a board on a hinge. Some doubly compound leaves have pulvini at the base of each leaflet and at the base of each pinna as well as at the base of the primary petiole itself. When such a leaf is pinched, the leaflets (pinnules) fold together, the pinnae hang downward, and the whole leaf droops from the twig. If the stimulus is very slight, the reaction will affect only part of the leaf; as the stimulus becomes progressively stronger the reaction becomes proportionately greater. Plants with pulvini are fascinating to watch. The movement takes place with surprising quickness; one feels almost as if he were watching an animal. A number of tropical trees and smaller plants are endowed with pulvini. The most famous example is the sensitive plant (*Mimosa pudica*), found natively in many parts of Mexico, where it is called *verguenza* ("shame").

The legend of man-eating trees and vines in the jungles of Brazil or Borneo that have the power of seizing animals and men in their movable "tentacles" is legend only. Quite another thing, however, is the fact that certain trees and other plants can produce injury or even death by caustic substances found in their tissues, usually in the leaves. Common examples are poison ivy, poison oak, and poison sumac. Many tropical trees contain juices much more virulent than these.

ORGANS OF REPRODUCTION

The reproductive parts of a tree are its flowers and fruit. All trees produce flowers, although these are often so small as to escape notice. Some trees, however, do not produce fruits, for a variety of reasons. Where fruit is present, it usually, but not always, contains seeds, for sometimes the seed fails to develop, even though the fruit does. On the other hand, seeds, where found, are mostly found inside a fruit, for by definition the fruit is the part that encloses the seed. The kinds of nonedible fruits are greatly in excess of the kinds of edible fruits. The apples, pears, and oranges are comparatively rare by the side of the vast numbers of elms, ashes, oaks, eucalypti and others whose fruits in the botanical sense are not the fruits of commerce.

Some kinds of trees reproduce themselves vegetatively, that is, without the formation of seed. Some kinds habitually reproduce in this way; others do so optionally; others only under extraordinary circumstances; others are unable to do so. A tree may reproduce vegetatively by (1) sending up shoots from the roots; (2) growing a new individual from broken-off twigs; (3) growing from broken-off or cut-off branches or limbs; (4) having its buds grafted onto another stock; (5) by air-layering. Examples of the first method are the live oak, the silver poplar, the jujube, and the hackberry, all of which sucker profusely. Examples of the second and third methods are the willows and the gumbo-limbo (*Bursera simaruba*), which, even though sawed up into firewood, sometimes grow new trees from each piece. One of the reasons the river willows have spread so greatly is that broken-off twigs and branches are carried downstream, lodge on sandbars, and grow into new trees. Examples of the fourth kind are the common grafts made on pecans, apples, and other valued fruit trees. Grafts are possible only among members of the same botanical family. Pecans may be grafted on hickories (and vice versa), and apples may be grafted on pears (and vice versa), but oaks may not be grafted on elms, nor sycamore on pine.

A vegetatively reproduced tree is almost exactly like the one it springs from. For this reason, selected varieties are grafted or budded onto other scions so as to produce as nearly as possible the desirable characteristics. A tree grown from seed, however, is an entirely new individual, containing hereditary factors from two parents, and hence subject to variation. That the offspring is not always like the parents is as true among trees (seed-produced) as among animals or people.

As observed above, all trees produce flowers, varying in size from the inconspicuous, colorless inflorescences of the elms to the brilliant, showy, large-petaled flowers of the magnolia, the royal poinciana, and the tulip tree. Flowers are different in size, in color, in structure, and in number of parts. Some have four, five or six petals, some have none. Some have well-developed sepals, others have rudimentary ones or none at all. Some have as many as fifty or more stamens; others have two, three, four, or five. The sepals and petals, although usually the most conspicuous parts of a flower, are not the essential parts: these are the stamens and the pistils.

The two essential processes in the formation of seeds are *pollination* and *fertilization.* Pollination is the transfer of pollen grains from stamen to pistil, and fertilization is the union of pollen cell with an ovule. If either of these processes is incomplete, no seed is formed. Pollination is sometimes interfered with by heavy rains, snow, high winds, or other adverse weather conditions. It may be prevented by certain kinds of hormone spray. Some plants produce pollen before the pistils are mature, and contrariwise some pistils mature before the pollen grains are ripe. Sometimes the insects that are needed to transfer the pollen from stamen to pistil fail to appear at the right time. In all such cases, pollination, and consequently, fertilization, cannot take place, and no seed is formed, even though stamens and pistils may be individually intact.

A flower is said to be perfect when it contains both stamens and pistil. It is imperfect when it contains only stamens or only pistils. Flowers that contain stamens only are called staminate flowers or male flowers, since the production of pollen is considered analogous to the production of spermatozoa in the animal body. Flowers that contain pistils only are called pistillate or female flowers, since it is in the ovary of the pistil that the embryo develops, as it is in the body of the female that the animal embryo develops. A perfect flower can fertilize itself (although it may also be cross-pollinated). An imperfect flower is useless by itself; the pollen produced by a staminate flower must be transported by some means to a pistillate flower. If both types of flowers are not present within reasonable distance of each other, pollination and resultant fertilization cannot occur.

On some kinds of trees all flowers are perfect. On other kinds, flowers are imperfect, but the arrangement of the imperfect parts varies from kind to kind. Sometimes male and female flowers occur irregularly distributed on the same tree; sometimes on the same branch; sometimes in the same cluster. Sometimes male flowers occur on one (individual) tree, female flowers on another (individual) tree; in such cases the tree (species) is said to be *dioecious*, which is the Greek way of saying that husband and wife live in separate houses. In the cases where both male and female flowers occur on the same tree, that kind of tree is called *monoecious* (Greek for "living in the same house"). Willows, poplars, mulberries, Osage orange are dioecious. A tree of this kind must be either male or female; it cannot be both at the same time. Oaks, elms, and hackberries are monoecious. They can pollinate and fertilize themselves, so that one oak tree, for example may produce acorns year after year even though all other oak trees in the world were destroyed.

Knowledge of a tree's sex has extremely important practical applications. For example, dioecious trees must be planted near one another if seed and fruit are desired. Sometimes a tree fails to bear fruit because it is either male or female and the complementary sex is not present. (If it is male it will of course never bear.) If fruit is desired one male tree should always be planted with a group of female trees. As in animal husbandry one bull can serve a herd of cows so one staminate tree will pollinate a number of pistillate ones. Similarly as animal breeders select the most vigorous bulls and cows for the production of a more vigorous race so plant-breeders select the best trees for cross-pollination. Practical knowledge often precedes theoretic understanding. Ancient pictures represent the Egyptians of 2000 years ago hand-pollinating their date palms although they could not have understood the mechanisms involved.

The objection to certain dioecious trees that bear undesirable fruit such as the Osage orange and the mulberry can be overcome by planting only male trees. Some dioecious trees are considered by many objectionable in both male and female form: the cottonwood, for example, whose staminate flowers form in long, sticky catkins that make litter on the street and sidewalk, and whose pistillate flowers produce the cottony tufts that float through the air for days.

Monoecious trees that are ordinarily self-pollinating may be cross-pollinated artificially by early removal of the stamens and subsequent transfer of pollen from another tree.

After pollination and fertilization have taken place, the part of the plant that becomes the edible portion is sometimes the seed itself, as in the various kinds of nuts; sometimes the enlarged and ripened ovary, as in the banana; sometimes the enlarged receptacle (part of the stem in which the stamens and pistil are set), as in the apple. When we eat a pecan, we eat the seed proper and discard everything else. When we eat a banana, we eat the ovary and throw away the receptacle (the skin). (The aborted seeds are visible as tiny black specks embedded in the fleshy ovary.) When we eat an apple, we eat the receptacle and throw away the ovary (the hard core with its seeds).

Trees are divided into two great groups, the gymnosperms and angiosperms, according to their manner of producing seeds. The gymnosperms ("naked seeds") are so called because their seeds lie exposed to view inside the structure bearing them. An example is the pine tree, whose seeds are plainly visible at the base of each scale of the cone.

In fact, the entire group of conifers, or cone-bearing trees—the pines, firs, spruces, redwoods, and similar trees with needle-like leaves—belong to the gymnosperms.

The angiosperms ("covered seeds") receive their name from the fact that their seeds are entirely concealed with the enveloping fruit. An example is the apple tree, whose seeds are well protected and concealed in the very center of the fruit. In popular terminology it is preferable to reserve the term "fruit" to the angiosperms since its definition can hardly be broadened to include the cones or other seed-bearing structures of the gymnosperms. The broad-leaved trees, including nearly all the familiar shade and ornamental trees, are angiosperms.

Tree fruits exhibit as much diversity in size, shape, and structure as do the leaves themselves. The difference between the pine cone and the apple are not more striking than the difference between a locust pod and a cherry, or between the winged fruit of the maple and the dancing ball of the sycamore. Botanists have given special names to the many different kinds. Fruits like those of the locust and mesquite (and bean and pea) are called either *pods* or *follicles,* according to whether they dehisce, or split open, at maturity along two sutures or one. They are also called *dehiscent* fruits. Fruits that do not split open, whether pods, follicles, or any other kind, are *indehiscent.*

Fruits like the cherry, peach, and plum (the "stone fruits") are called *drupes.* Dry winged fruits like those of the ash, the maple, and the elm are *samaras.* Hard, dry, indehiscent fruits are *achenes.* Fleshy fruits with the seeds distributed in a hard core, like the apple, the pear, and the quince, are *pomes.* Fruits like the strawberry, raspberry, and magnolia (developed from the multiple ovaries of a single flower) are *aggregate fruits.* Fruits like the mulberry, the fig, and the pineapple (developed from the partly fused ovaries of several flowers) are *multiple* or *collective fruits.*

Fruits serve not only as protective containers for the seeds within but also as the distributing and propagating agency for these seeds. It is to the tree's advantage to send its offspring as far away from itself as possible, so that they will have a better chance to develop and will not compete with the parent tree for space and food. The mechanisms by which translocation of the seeds is effected are very ingenious. Certain of the dehiscent pods open violently with a twisting motion that propels the seeds to a considerable distance. The double samaras of the maple are provided with wings that carry them (and the seeds within) to a little distance as they glide or twirl downward. On the fruit-balls of the sycamore each seed is outfitted with a tiny parachute so that with a little wind it blows far away. The coconut is adapted for transportation by water, sometimes circumnavigating the globe. Some fruits are furnished with hook-like appendages that cause them to stick to animals and hence be transported. Some, particularly the small drupes like those of the anaqua and hackberry, are attractive to birds, which while eating them unavoidably carry away the seeds. Some fruits are eaten by animals; the seeds of these, having a hard coat that resists digestion, pass through the animal's alimentary canal unharmed and are deposited with the droppings, thereby being not only transported but fertilized at the same time! Many fruits are, of course, eaten by man, and the seeds of these are transported in two ways: (1) accidentally, as when we spit out a grape seed or persimmon seed, and (2) intentionally, as when we seek out the best seeds and plant them.

II

PLANTING

PLANTING IS AN ACTIVITY that has always fascinated the human mind. It is perhaps the most constructive and creative phase of the agriculturist's work. Regarded as a science, it may be said to reach its most technically advanced state, and as an art its culminating point, in tree moving,[1] where man, surpassing nature, removes a large tree from its natural location and sets it down intact in a location of his choosing.

Few things are more satisfying spiritually than the planting or transplanting of a tree. According to an old proverb, he who plants a tree loves other people.

There is the story of a young man who was advised by a friend to plant an apple tree. "No," he said, "it takes too long to grow; besides I haven't got time."

His friend suggested the idea to the man's father.

"No," he said, "I'm getting to be an old man, and I'll be dead before any tree I plant grows up."

The friend then took the project to the man's grandfather, who, agreeing that it was a good idea, planted the tree, watered it, cultivated it, and lived to enjoy its fruit.

What could better represent the growth of a family than the simultaneous growth of a tree? A young tree fitly marks a marriage or a birth: it is a beginning; it stands for youth, hopefulness, future. As it broadens and enlarges through the years, it symbolizes the broadening of the couple's ambitions and the enlargement of their fortune. Becoming still larger and heavier it comes to symbolize the stability and permanence of a well-established household. At its maturity it represents the quiet dignity of old age.

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[1] The term "transplanting" is usually applied to shrubs and to trees four inches or less in diameter, while "moving" is applied to large trees where large balls of earth are involved and special equipment is needed.

WHAT SIZE?

What size tree shall I plant, is the first question homeowners ask; the second question is, what kind? Obviously, the smaller the tree, the more easily it is transplanted and the less it costs, but the longer it takes to grow. If you want immediate shade, you should get the largest tree possible. If your budget is limited and your time is unlimited, you may well start with a series of small trees.

As in investing money where the risk is greatest, the chance of gain is largest, so in transplanting trees, where the risk of the transplant's dying is greatest, so the possible gain is largest, should it live. Small trees experience very little shock in moving and are almost certain to grow, even though set out by unskilled hands. Large trees, on the contrary, suffer considerable shock, even though moved by experts. The homeowner should entrust the moving of large trees only to the most experienced men and should insist on some kind of guarantee. (The usual guarantee is that if the tree dies within six months under reasonable care, it will be replaced at half the original cost.)

If there is an optimum size in selection of transplants, it is probably a tree of 4–6 inches in diameter and 18–20 feet in height. Such a tree is not too small to mean years of waiting for shade and not too large to make its moving costly and dangerous. Trees of this size, skillfully moved and properly watered and fertilized, will grow vigorously, producing appreciable shade in the second or third year. Although theoretically no tree is too large to be moved, in practice the cost and mortality risk on trees of 10 or 12 inches or more becomes disproportionately great.

WHAT KIND?

The question of size is intimately bound up with the question of kind, or species, i.e., some trees are more easily moved than others, some grow faster, some live longer, etc.

Among the most desirable, all-purpose trees are the American elm, the sycamore, the pin oak, the red oak, the white oak, the hard maple, the ginkgo, the tulip tree, the ash, the linden, and the sweet gum.

Each section of the country has its favorites to add to the list. In the South there are the live oaks, the pecan, the Spanish oak; in the Northwest the pines, firs, and spruces; in the East and North the birches, the walnut; in Florida and California the palms, the eucalypti, and so on. The ideal kind of tree to plant should be:

(1) Naturally adapted to the climate and soil where it is to be placed, as proved by others of the same kind growing wild or transplanted in the same area
(2) Hardy and relatively immune to diseases
(3) Of reasonably rapid growth
(4) Long lived
(5) Straight and well formed
(6) Adapted at mature size to the space it is intended to fill.

Of these characteristics, rapidity of growth is probably the least important, while hardiness and adaptation are the most important. Much depends on your objective. If immediate shade with no view to the future is desired, some very fast-growing tree, such as Chinese elm or chinaberry, may be planted. If, however, a permanent investment is contemplated, then a nobler, sturdier, and longer-lived tree, like one of the oaks, should be planted.

Many people avoid the horns of this dilemma by planting two trees at the same time: one a slow-growing tree of a highly desirable variety and the other a fast-growing tree to be cut down at a later date when the first will have developed to agreeable size. It should be noted, however, that while many "good" trees are slow growing, it does not follow that all fast-growing trees are necessarily "bad." The sycamore, the eucalyptus, most of the elms, and some of the oaks grow very rapidly and still make excellent trees.

Although there are a number of trees that will meet the above qualifications, there are more that will not. In choosing further among those that do qualify, the personal tastes of the owner must guide him. With trees, as with politics, there exist wide divergences of feeling, even within an established frame of common agreement. Some people worship the sycamore as the most beautiful of trees; others curse it as a nuisance because of its large leaves and fluffy fruit balls. Some believe the American elm the world's best tree; others hate it because of its ubiquitous roots. Some consider the tree of heaven an object of adoration; others sneak out at night to pour kerosene around its roots. *De gustibus non disputandum est.* All the tree expert can do is to recommend certain trees for a certain locality. From such a list the homeowner is free to pick out the ones he favors.

It should also be noted that trees suitable for a lawn are not necessarily suited for streets and avenues. Although lawn trees may justifiably be wide spreading, short lived, even "messy," trees intended for parkways should be none of these. Their qualifications are much more strictly delimited. They should form a compact head, affording much shade, but neither too tall nor too wide. If too tall, they conflict perpetually with overhead telephone and power lines and constitute a danger to pedestrians and automobiles underfoot; if too wide their limbs hang down into the street. They should be extremely hardy and long lived, in order to resist the difficulties of their environment: cement slab on one side, sidewalk on the other, thoughtless passersby who hack on their trunks, and scrapings and collisions from automobiles. They should be more or less "clean" in their fruit and leaves, for any tree which makes conspicuous litter underfoot is sure to meet with public disapproval, however meritorious it may be in other respects. They should be strong wooded, able to withstand storms; and finally they should be attractive and shady, for this is their entire purpose.

To find a tree having all these characteristics is indeed difficult; and the problem is complicated by the fact that each region must find trees suited for its particular climate, soil constitution, and biological environment. Those who are unfamiliar with trees commonly in use in their area will find helpful an evaluation made by members of the National Shade Tree Conference for the several regions of this country and published in its Proceedings

Most cities manage to solve the problem in time, some more successfully than others. It is interesting how we associate certain trees with certain cities. Often the dominant impression a city makes upon us consists of its beautiful tree-lined avenues; these we remember long after the confused impressions of building, museums, and store windows have faded away. Berlin is (or was) famous for its avenue of lindens, Paris for its poplars and horse-chestnuts, Japan for its cherry trees, Mexico City for its ashes, Los Angeles for its palms. An examination of the cities of the world will reveal that almost every kind of tree has been tried at some time or other as a street tree.

In this search for the ideal street and avenue tree one caution should be observed: it is probably not wise for a city to plant one tree exclusively, for in the event of an epidemic of some kind she might face the loss of all.

WHERE TO GET IT?

After settling the question of kind and the question of size, the third question is where to get the tree. Shall it be dug up in the neighbor's yard, dug in the woods, or bought from a nursery? If the moving is to be done by a tree expert, that problem is of course his. However, for the benefit of those experimentally minded homeowners who undertake to move trees on their own, a little discussion of this issue is not amiss.

Wilding trees (those growing in the woods and never having been moved or root-pruned) ordinarily have a long, straggly root system which makes them difficult to transplant; moreover the soil is often rocky and difficult to work in. Nursery-grown trees, on the other hand, are usually root-pruned from time to time in such a manner that they develop a dense, compact mass of roots confined within the limits of a reasonably small ball. In addition they are grown in the best possible kind of soil: rich, light, ideal for digging and balling. Wherever possible, the nursery-grown tree is to be preferred.

On occasions, however, where no large-sized or desirable nursery trees are available, or where it is wished to move a particular tree from one location to another, then there is nothing to do but to accept the adverse conditions characteristic of the wilding tree and attempt to overcome them.

Whatever tree is settled on for moving, it should be thrifty, vigorous, full-limbed, free from cavities, bark disfigurations, twig or leaf diseases, or any other kind of abnormality. No tree in a declining condition should be moved. Similarly, no tree should be chosen for moving that is close to a sidewalk, street, building, or other tree, for half its roots will be unavailable for digging.

It should also be remembered that the limbs and crotches of a young tree will not increase their distance from the ground as the tree grows; thus a large limb or a low crotch three or four feet from the ground will always remain at that level unless cut off. (Many people are misled on this score, believing the tree to grow all over as an animal does.) Generally it is preferable to select a tree with straight trunk, free of limbs up to a height of 5 or 6 feet. However, low crotches or low limbs are not always undesirable, much depending on the kind of tree, the location, and the purpose it is desired to serve.

PREPARING THE HOLE

The hole should be prepared before the tree is moved. It should be dug larger than the exact measurements of the root system to be transplanted, preferably twice as large or in certain situations still larger. That is, if the roots measure 4 feet across and 2½ feet deep, the hole should measure 8 feet across and 4 to 5 feet deep. In poor soil, the enlargement of the hole is particularly necessary. All rocks and undesirable soil are carted away, and the hole is partly refilled with prepared soil of the mixture best suited to the kind of tree to be planted. The reason for making the hole larger than apparently necessary is easily understandable, for when the root-system, which has been trimmed back to the edge of the ball, begins to grow, the thousands of new rootlets that push outward will more readily enter the filled soil that has been loosened and enriched than they would the rocky, inhospitable rim of the original excavation.

Ordinarily, the digging of an extra large hole and the refilling with imported soil is sufficient provision for giving the transplant a good start. In unusually rocky, clayey, or tightly compressed soils, however, dynamiting is sometimes resorted to to loosen up the ground.

In some kinds of soils drainage provisions must be made. It is perhaps not generally realized that a tree can be killed by too much water as well as by too little. Any tree whose root system is completely submerged in water will die in a short time. Proof of this, in the form of dead trees, may be easily found in regions where floods have left water standing around trees or in regions where swamp levels or lake levels have suddenly risen and entrapped nearby trees. Even the trees most intimately associated with water—willow, cypress, cottonwood, box elder—grow on the river bank, not in the river channel.

All tree roots must have air, and that air must come to them through the tiny pores of the soil. When the air supply is shut off by flooding (or by superimposing layers of heavy soil), the tree dies. Many times a heavy clay layer of soil exists, or is artificially made to exist by poor cultivating practices, under the surface soil. This "hardpan," as it is called, prevents the normal draining away of water, and in times of excessive rainfall or excessive watering, so much water accumulates in the surface soil that trees in this area die by asphyxiation. Such a hardpan layer sometimes exists many years, even around favorite trees, without coming to notice until certain changes in the environment develop its potential hazard. The commonest example is that of a tree that suddenly dies after shrubbery has been planted around it. Does the shrubbery cause the tree's death? No, not directly, but indirectly yes, because of the stepped-up watering program given the shrubs, with the result that an unusual quantity of water accumulates around the tree, and it dies. In such cases the shrubs, with their shallower root system, may live on, and the owner may never suspect the truth.

In locations where drainage is suspect, it may be improved by incorporating sandy loam or quantities of humus into the soil. The planting hole may be dug unusually deep and partly filled with gravel to make sure that water will drain away from the roots. In extreme cases there may be installed an underground drainage system consisting of tile pipes slanted in such a manner as to carry water away from the roots.

DIGGING THE TREE

With the tree selected and the hole dug, there remains only the actual moving of the tree. Digging out the tree, moving it to its new location, and planting it should be done as carefully as possible and without unnecessary waste of time. The less time lost in transit from old site to new site the better the chance of survival. Tree roots dry out rapidly in air and sun. A tree out of the ground is like a fish out of water; and although it may be made to survive in a state of suspended animation for a considerable length of time, its roots are nowhere so well off as in the ground.

Trees are moved in two ways: bare-rooted, and balled and burlaped. Bare-rooted trees are the easier to dig and move because of the little weight involved. Balled trees of any size must be moved with special equipment because of the very great weight of the balls of earth.

Most deciduous trees may be moved bare-rooted if not over 3 or 4 inches in diameter. Some species, such as the sycamore, the poplar, and the American elm, experience very little shock in being moved. Others, while they survive, lose a year or so in re-establishing themselves. In some localities they may be moved either in the fall or the spring indifferently. The advantage of fall planting is that the roots have an opportunity to become active very early in the spring and hence gain a start over spring-planted trees. In regions where winters are severe and prolonged, tender trees are best planted in the spring.

A bare-rooted tree should be dug out with considerable care. A circular trench is dug around it about 3 feet deep and 2½—3 feet removed from the trunk. All the roots encountered in this trench are severed cleanly with axe or shears. Then slowly and carefully the dirt is worked loose from the roots within the circle, the taproot (if any) is cut off as low as possible, and the tree is lifted out of the hole. All broken roots are cut back; all cut and skinned surfaces are painted; the roots are covered with wet straw, wet newspapers, or better still, stuck into a mud bath, and the tree is taken as rapidly as possible to its destination. Cloudy, rainy days are the best for transplanting. If the sun is out, the roots should be shielded from its rays. As many of the tiny fibrous roots as possible should be preserved: they are the true feeders, and if they are destroyed, the muscular roots must grow new ones before the tree can draw anything out of the soil. Since the fibrous roots of balled trees are not disturbed, these suffer less shock than bare-rooted trees.

Most trees over 4 inches in diameter should be moved with a ball of earth surrounding the roots, although in former times before special tree-moving machines were available, many large trees were moved bare-rooted. All evergreens should be balled.

Balled trees are harder to move but easier to dig. The digging begins with a circular trench, as for a bare-rooted tree. As the trench is deepened, the roots are cut off cleanly with axe or shears and painted over. Care is taken not to break the ball or to loosen the roots within the ball. At the bottom the trench is tapered in toward the center, thus rounding off the ball. The final, underneath cut is made by hand tools, if the ball is small, or by a winch cable, looped around and pulled through, if the ball is large. (Burlaping, however, should precede the undercutting.)

The size of the ball is, of course, in proportion to the size of the tree. The usual rule is 8 to 10 times the diameter of the tree trunk—that is, a tree 6 inches in diameter is moved with a ball 48 to 60 inches across; a tree 4 inches in diameter should have a ball 32 to 40 inches across, etc.

In large trees (one foot through or more) the tree should be prepared for moving two years ahead of time. The circular trench is laid off, as just described, but is dug in sections. Suppose the trench to be divided into six segments. The first year three non-consecutive segments are dug, the roots severed and painted, and the dirt replaced and perhaps richened. The next year the remaining three non-consecutive segments are dug, the roots in these areas cut, and the dirt replaced. The third year the trench is reopened all the way around, and the tree is ready to be moved.

Cutting the roots while letting the tree stand is a method of root pruning that forces the development of new fibrous roots within the ball to be moved. Spreading the work out over three years prevents the tree from experiencing too great a shock at one time. Actually the work could be spread out over five or ten years, if it were not for the fact that by the time the last segments were dug, the roots in the first segment would have grown back to their original proportions, and the work would have been done in vain.

The exact shape of the ball varies with the kind of tree. Trees with a long taproot, such as the pecan, should have a long, conical ball. Those with shallow, wide-spreading roots, such as the elms, should have a wide, flat ball. Those with deeper roots, such as most of the oaks, should have a ball more nearly equal in width and depth. Rarely is the "ball" actually a ball; more generally it is conical, truncated, ovaloid, or even square.

The objective is, of course, to shape the ball in such a manner that the greatest number of roots is contained within the smallest possible area. The more roots that are moved with the tree the better; on the other hand dirt is extremely heavy, a cubic foot of average soil weighing about 110 pounds. A rapid way to estimate the weight of a ball is the following: Square the diameter of the ball (in inches); multiply this by its depth (in inches); subtract one-third from the total; and multiply the total by .075. The result will be the weight in pounds.

PREPARING THE BALL

Once the ball is shaped, the problem is how to lift it out of the hole and hoist it onto the conveying vehicle without breaking the ball or loosening the roots. There are several solutions to this problem.

In the North when the ground is deeply frozen, a ball of earth may sometimes be hacked out and moved as one frozen mass without wrapping of any kind. In some kinds of heavy, gumbo soil the same thing is true: the dirt can hardly be knocked loose with a hammer. Some kinds of palms can also be moved without wrapping, their fibrous roots being so numerous and so tightly intertwined as to hold the soil effectively.

In extremely sandy soil, on the other hand, it is as difficult to hold the ball together as it is to weave the traditional rope of sand. In such cases the box method is used. A trench is made as usual, but square not round, and tapered inward somewhat toward the bottom. A box of heavy oak boards—bolted, not nailed, at the corners—is built up around the square "ball." Other oak boards are worked under the bottom and bolted to the side boards. These bottom boards are cut longer than the width of the ball so that their ends protrude. Strong hooks are fastened to the protruding ends, ropes are tied to the hooks, and out of these a rope cradle is built up. A truck with winch and A-frame then hooks onto the rope cradle and hoists the box and tree straight upward. In this position the tree can be moved to the planting site, if nearby, or it can be transferred to a flat-bed truck, if the haul is to be a long one.

The most commonly practiced method, however, is to wrap the ball tightly with burlap and/or canvas. Nearly all small nursery plants *are balled and burlaped; hence the designation "B and B."* It might seem that burlap would not be strong enough to hold together large balls of earth; but when it is wrapped tightly and properly and reinforced with a canvas overwrap, it is adequate for everything except the most unusual cases.

The burlap used is in the form of cut-open burlap sacks. The sacks are wrapped as tightly as possible around the ball and are pinned together with special nail-pins at every point where they overlap. For very small balls one or two sacks are enough to complete the wrapping. For large balls many sacks must be joined together.

After the ball is wrapped as snugly as possible, it is further secured by lacing. "Lacing" means the enwrapment of the ball by small ropes, about the size of a window sash cord. These ropes are wrapped in such a way as to form a tight net firmly holding the ball together. Insterstices of the net may be 4–5–6 inches wide, according to the manner of lacing. Small balls need not be laced; large ones must be.

LIFTING AND LOADING

Once the ball is burlaped and laced, it still needs to be hoisted out of the hole and onto a conveyor. There are several methods by which this may be done.

The problem is not so much the weight of the ball, although this often runs into several tons, as the method of attachment, for the lifting must be done against the ball of earth, never against the trunk, which is easily damaged.

Various kinds of rope or canvas slings are used for this purpose. The sling is placed around one side of the ball, and the ball is tilted over upon it. The ends of the sling are attached to a winch line suspended from an A-frame or to a chain hoist mounted on an I-beam running the length of the truck. Improved types of slings, consisting of metal bands or rubberized belting, which are made to fit snugly about any size ball, have recently appeared on the market. The advantage of the sling is that, like the box, it allows the tree to be carried in a horizontal position for a long haul.

Another interesting method is to work a heavy round iron plate under the ball; then to force a heavy iron rod through the ball in an upright position close to the trunk, taking care not to damage the roots. The rod fits into a special slot in the plate, where it is secured by a pin passed through a hole in its tip. The upper end of the rod, left sticking out of the ball one or two feet, terminates in an eye, to which a winch cable is fastened. The tree may then be lifted straight up and transported in this position to the new site. Disadvantages of this system are the difficulties of working the plate under the ball and guiding the rod to find the slot. Whenever it is possible to tilt the ball over slightly, these difficulties are obviated.

A third method is to slide the ball onto a platform made of strong oak planks securely bolted together with stout cross pieces on the underside. One side of the trench is enlarged to form an inclined plane, and the platform is slid up the inclined plane to ground level.

For sliding the ball onto the platform a mat made of woven ropes, rubber strips, or close-meshed fence wire is useful. The mat is looped over the thither side of the ball and pulled by ropes fastened to its ends, hammock fashion. The platform has iron rings along its edges to which chains or cables are attached for pulling it up the slope out of the hole. Motive power is furnished by a winch truck, anchored in front to a distant tree or stump. When the tree reaches ground level, it may be slid onto a low-boy trailer and transported upright, if not too large.

Special tree-moving trucks and trailers are now manufactured that will load trees easily and efficiently. However, any large, strong, flatbed truck can be equipped to do the work for all except the very largest tree. The essential elements are two overhead metal arches from which is suspended an I-beam with a traveling hoist.

A large tree that is to be taken very far needs to be tied securely to the truck to prevent side-lash and damage to branches or trunk. Branches of spreading trees need to be drawn together with a rope. Right-of-way should be obtained ahead of time, the shortest route mapped out, bridges tested, etc. Four to seven men are needed to transport and plant a large tree.

PLANTING

When it reaches the planting site, the tree should be taken off the truck with great care and set into the previously prepared hole. If it is bare-rooted, it can usually be handled by five or six men. If it has a small ball, it can be rolled down an inclined plane made by leaning planks against the edge of the truck platform. If it has a large ball, it is lifted by a chain hoist, a winch line passed through an A-frame, or some similar device.

The tree should be planted at the same level at which it was formerly growing. If set too deep, its roots may suffer from suffocation. If set too shallow, they may dry out in the air and sun. Elms, in particular, have roots very close to the surface, usually buttressing out from the trunk several inches above the ground.

Bare-rooted trees need to be planted more carefully than balled trees. Broken or scarred roots are cut back and painted over. Crisscrossing roots are eliminated as much as possible. The tree is set in the center of the hole and lined up straight both on its north-south and east-west axes. If a small tree, one man can hold it straight while the others shovel in the soil. If a large tree, it can be conveniently kept supported by ropes.

If there is a drainage problem, gravel or sand should be placed in the bottom of the hole to prevent water from standing around the roots. The hole is then filled with good, rich, porous, well broken-up soil. If there is no drainage problem only soil need be used. The subsoil excavated when digging the hole is, of course, discarded.

The soil is worked very carefully around the roots, patted and tamped firmly with the hands, fists, and, where no injury will result, with the feet. It is not enough just to shovel the soil in and assume it will pack itself. It won't. Air pockets will be left, with the result that some roots will remain out of contact with the soil; and later with the first rain or first heavy watering the soil will sink and puddle.

Fill all spaces under and in between the roots. Do not double the roots upon themselves or bend or twist them in any way. Where a root is too long for the hole, make the hole bigger or shorten the root; do not force it into a bent position. Lay out the roots gently, caressingly. Try particularly hard to keep from damaging the small, fibrous rootlets, which are the true feeders. Extend, fill, pat, and tamp. Gradually build the soil up to the consistency and firmness of long-established soil. Try to deceive the tree into thinking that it is in its native bed. Build up a ring of earth around the rim of the planting hole to prevent water from running off.

Balled trees are easier to plant. The ball should be lowered carefully into the hole, which is previously measured so that when the ball comes to rest, its upper surface will be approximately even with the surrounding soil. When the platform is used, it must be removed without injury to the ball. The tree is set as straight as possible. Before the lacing is taken off, the ball may be moved and twisted about to a limited extent even after it is in the hole. After the lacing is removed, however, the trunk should not be pushed on or the ball twisted, since the soil may break away from the roots. The lacing and as much as possible of the burlap wrapping should be removed, though the burlap will quickly decay if it is too difficult to remove.

Good soil is then shoveled into the trench around the ball and tamped down firmly. A ring of earth is built up around the planting hole, just as with the bare-rooted tree.

WATERING

Contrary to common practice, the hole should not be watered just before or during planting. Watering at this time makes planting more difficult, prevents tamping, and causes the formation of clods, which when dry can hardly be broken up. Watering is therefore best done after the planting operation is finished. It should then be done copiously but slowly.

Open the hose moderately, put a board or a rock within the ring of earth, and let the water fall on the board and spray out, to reduce its erosive action. Let the water run three or four hours. Do not repeat until the soil seems to be getting dry. This will mean watering once or twice a week, according to the nature of the soil and the kind of weather.

Remember, too much water is as harmful as too little. The soil should be kept moist but not saturated. Sprinkling and other forms of superficial watering are of little value; they may actually be harmful by encouraging the roots to grow too close to the surface. Flooding is similarly doubtful. Since water can be absorbed by the soil only at a certain rate, a great quantity of it poured out in a short time is largely wasted.

FEEDING

Newly planted trees sometimes benefit from an application of plant food. It is, however, a common mistake to use too much fertilizer or too concentrated a dose. Like watering, feeding can easily be overdone. It is perhaps better to use no fertilizer than to use the wrong kind. Good rich soil placed in the planting hole is ordinarily adequate.

Where some kind of plant food seems desirable, however, it may be added in the form of well-rotted manure or bone meal (the safest of fertilizers) in quantities not to exceed three pounds per inch of trunk diameter. The fertilizer should be thoroughly mixed with the dirt, not just dumped in one segment of the hole. In the case of balled trees, it may be applied within the ball by the punch-bar method, or it may be mixed with the soil in the surrounding trench. Commercial fertilizers are not recommended for immediate use on transplants.

BRACING

The transplanted tree usually needs artificial support until it can establish itself. If allowed to blow about in the wind, the new, developing rootlets will be broken.

Guy wires are most commonly used for this purpose. Three or four wires (small cables) are attached to stakes driven in the ground equidistantly around the tree. The stakes should lean away from the tree and be notched on the far side. The wires are fastened to the tree by wrapping them around cushions of burlap or canvas, or running them through short lengths of rubber hose. On large trees they may be attached to lag screw hooks. (See chapter on Cabling.) The disadvantage of wires is that they are a tripping

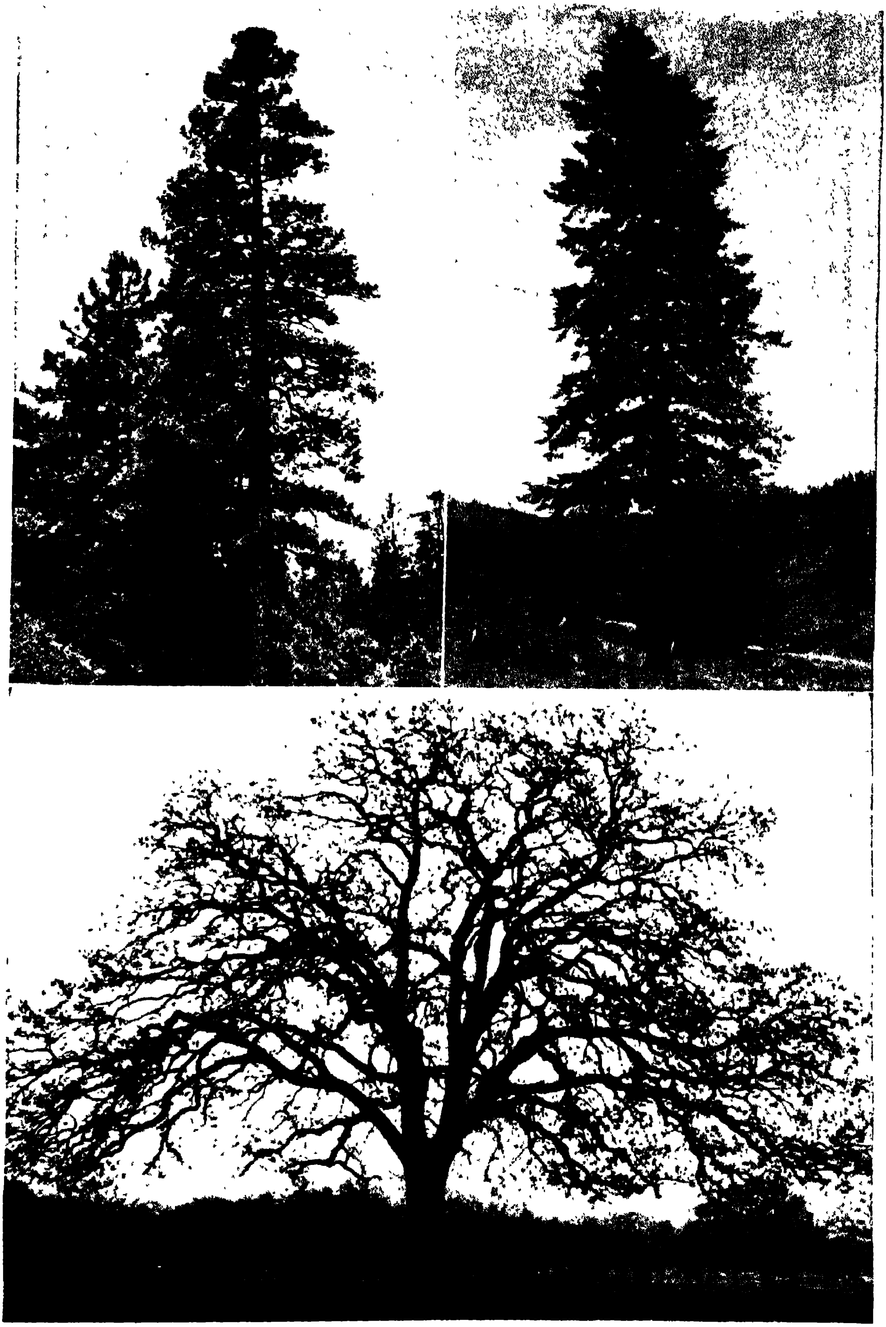

Plate 3. *Above:* Typical excurrent trunks: Ponderosa pine, *left;* Douglas fir, *right.* (U.S. Forest Service photographs.) *Below:* Typical deliquescent trunk, exhibited by the post oak.

Plate 1 PRELUDE TO TRANSPLANTING *Upper left* Cutting roots for wrapping in burlap The ball is dislodged by a winch cable looped around it and pulled through underneath The ball is then slid onto an iron plate chained to it, and slid to the surface in an upright position Fins are welded around the plate for the attachment of chains *Upper right* Lacing a balled tree Burlap and rope hold the soil in place The ball weighs about five tons though the trunk is only seven to eight inches in diameter *Below* A balled tree ready for moving, loaded by truck with an A frame and winch Rope guards minimize sway in transit

Plate 5A Moving a tree bare rooted A circular trench is dug and roots are cut off at that point Remaining roots are carefully uncovered and combed out

Plate 5B *Left* One way to brace a newly planted tree Note folded burlap under wooden blocks, lightly nailed in place *Right* Wrapping the trunk with special paper will prevent sunburn, desiccation, and attack by borers

Plate 6A. The green leaf, world's most important factory (American elm).

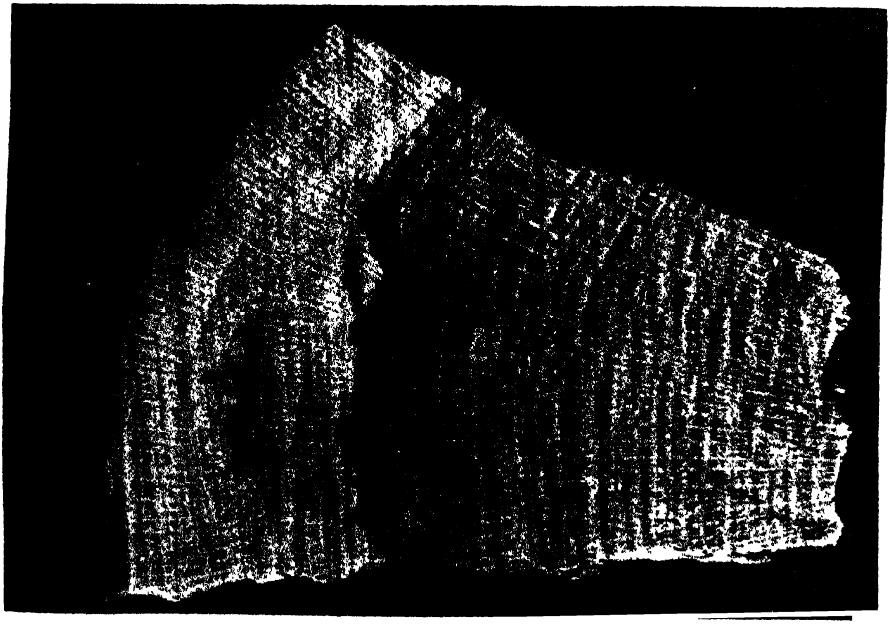

Plate 6B. A section of oak showing outer bark, inner bark, sapwood, and heartwood. Vascular rays run radially from near the surface toward the center. Growth rings can also be seen, particularly in the heartwood. Where rays and rings intersect, the effect is of small squares.

[illegible] visible by suspending [illegible] from them.

WRAPPING

The trunks of transplants, particularly small ones with thin, tender bark, should be wrapped with burlap or some other substance as a protection against sunburn, borer infestation, and the winter gnawing of rodents. A specially prepared tree-wrap material consisting of two layers of crepe paper with asphaltum in between may be obtained from horticultural supply houses.

The wrapping should extend from the ground up to the first major branches. It should be put on as one would tape a broom handle, making it as snug as possible and giving sufficient overlap at every turn to insure full protection. Wrapping is also excellent for discouraging sapsuckers, which sometimes make a young tree look as if blasted with buck-shot. The wrapping should be left on for two seasons or until it begins to be unsightly.

PRUNING

A transplanted tree needs its top pruned to compensate for partial loss of its root system. This may be done at the time of digging or at the time of planting. If done at the time of digging, this excess weight and volume will not have to be transported.

The reason for top-pruning is simple. Every transplanted tree suffers some damage to its root system. There are fewer roots left to supply the same top. More water is evaporated from the leaves than can be supplied by the reduced number of roots. Outgo exceeds intake. The result is disastrous. The tree wilts, loses its foliage, and dies back part of the way or all of the way.

But if the top is deliberately reduced to conform to the unavoidable reduction of root system, then a balance between the two parts is restored. All the limbs should be clipped back one-third or even one-half of their length. The leader should be cut only slightly or not at all. Many small twigs may be eliminated altogether, particularly on the inside of branches. If the tree is in full leaf, the leaves may be stripped off.

[illegible]

surface, does not destroy the tree's natural framework. The roots soon re-establish themselves, and in a short time the reduced top grows back to its original size. Since evergreens usually have a compact root system that is easily enclosed within a relatively small ball, they need less top pruning when transplanted.

For several years there have been on the market various wax preparations for use on transplants. Sprayed on foliage and trunk, they coat all surfaces with a thin layer of wax that serves to prevent evaporation very effectively. Many arborists use them on evergreens and also on deciduous trees that are being moved when in leaf.

HORMONES

Various chemical preparations called "plant hormones," composed of organic materials such as indolebutyric acid, have been marketed in recent years. These are designed to stimulate the rapid formation of new roots; hence they are useful in starting transplants.

The use of these materials is still in the experimental stage, although promising. Manufacturers' directions should be carefully followed. In good, rich soil there is little need for them.

III

PRUNING

PRUNING IS THE MOST widely practiced aspect of tree care and one of the most important. Of the tree expert's time about 60 per cent is spent on pruning, the other 40 per cent being distributed among cavity repair, spraying, fertilizing, cabling, transplanting, removing, etc. The tree expert may omit one item or even several items from this list of activities and still remain in business, but he cannot omit pruning. Pruning is the staple of his trade; the first tool he buys, and the last one he sells, is a saw.

Despite its paramount position, pruning is at least as much misunderstood and malpracticed as any of the other phases of tree work. Anybody can saw off a limb, we are told; and from the ground point of view, it must be admitted, the thing does seem simple enough; nevertheless, in practice, it turns out that almost nobody can saw off a limb correctly without instruction, and that even experienced tree workers may make 10 to 15 per cent of their cuts improperly.

It is hoped that the discussion which follows will help the homeowner to prune all the trees that are within his reach. With the right kind of tools the pruning of small and medium-sized trees is a comparatively easy job, once the principles have been grasped. The pruning of large trees, however, where special climbing skills and special equipment are needed, is better left to the professionals.

DEFINITION

Pruning means (1) the cutting out of all dead and diseased wood and (2) the cutting out or clipping back of any live wood considered necessary for environmental reasons or for training the tree into a desired form.

PRUNING DEAD WOOD

The cutting out of dead and diseased wood is of prime urgency; it is imperative not only for the tree's health and appearance but also for the safety of those who pass under it. Dead wood adds unnecessary weight to the tree, possibly causing it to split apart under strain when otherwise it would not have done so. Many dead branches are green along a region 4 or 5 inches out from their base, causing a diversion and evaporation of sap from the healthy tissues. Dead limbs fall in heavy winds or even without winds to damage automobiles, houses, fences, or pedestrians. Court records contain many curious suits that have been filed on this account. Worst of all, perhaps, dead limbs serve as breeding places for insects and focal points for decay-causing organisms. Sanitation, as important for the shade tree as for the fruit orchard, means the careful pruning out of all dead and diseased wood and its subsequent burning or hauling away.

PRUNING LIVE WOOD

The cutting out of live wood is a matter that calls for intimate knowledge of each tree, according to its kind and condition and surroundings. The most common reasons for cutting off sound limbs are: (1) their interference with power lines, proximity to houses, or interference with traffic of the streets and sidewalks; (2) their growth toward the inside of the tree rather than the outside (in the case of deliquescent trunks); (3) their rubbing against each other. In all such situations it is usually advisable to remove limbs even though they may be attractive and healthy. When two limbs are rubbing against each other, it is sometimes convenient to bolt the limbs together, but where this is not practicable, it is advisable to remove the smaller or less desirable one.

In pruning, the natural lines of a tree are followed as closely as possible. Some trees have upright habits, others are drooping; some are spreading, some are rounded, some conical, some massive, some dainty. Clearly, the same procedure cannot be applied to all.

To cut off all down-hanging limbs on a weeping willow would destroy its charm. However badly or strangely pruned, all trees tend to revert to their natural form as soon as possible. The skilled pruner works with nature, not against her, and tries to make more striking the effects which she has clearly intended.

In general, trees are trained to have a more or less open center. Branches growing on the inside of the main framework limbs are cut off to prevent choking up the tree's center. New shoots, called "suckers" or "watersprouts," which appear on the lower trunk are also removed.[1] The principle followed in such pruning practices is to divert the growth of the tree as much as possible toward the top and outside. (Topping, or pollarding, exactly reverses this process. It deliberately cuts back the top and sides of a tree in order to make the lower part bushier and branchier.)

Trees like the pines that have a central bole going straight upward with a series of radially branching limbs cannot of course be pruned to have an open center. In their case only dead, overlapping, and interfering branches are removed.

Pruning is usually the first step in the rejuvenation of a neglected shade tree. It is done before cavity repair, cable installation, feeding, or spraying. Pruners start in the top of the tree and work down, dislodging all "hangers" as they go. Pruners should exercise extreme care when working near power lines and should wear safety ropes at all times.

METHOD OF CUTTING

To cut off a limb correctly it is necessary to cut it at a joint: either flush with the main trunk, if it is a major limb, or flush with whatever limb it issues from, if it is a smaller branch. To cut flush without leaving stubs and lips or shoulders and corners is much more difficult to do than to say. While the idea is simple enough and readily enough grasped by anyone, its execution is a matter that calls for considerable skill and practice. The difficulty is caused by the fact that limbs emerge from trunks or parent limbs at every conceivable angle and in positions sometimes almost inaccessible. A good climber with a hand saw can make nearly all cuts well in small or medium-sized trees; but in very large trees, whose top and extremities cannot be reached by ladders or by climbing, and where reliance must be placed on long-handled pole saws, a certain proportion of cuts is sure to be made improperly. It is impossible to make flush cuts around corners, howsoever slight the curvature may seem. When the saw blade is not placed at the proper angle to the limb to be cut, the resultant cut cannot be flush. This fact is the key to good or bad work. To turn the saw blade at exactly the right angle for each cut, neither to one side nor the other, neither too deep nor too shallow, is the essence of good pruning.

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[1] Most people believe watersprouts should be removed because "they draw nourishment from the tree." This is false reasoning, for, having leaves, they help manufacture food for the tree as much as any other limb, although naturally using part of it for their own growth. They should be removed simply because large limbs—which they will become—are ordinarily not wanted at the points where they appear.

When a limb is not cut off flush, a stub or lip is left over which the tree cannot form a callus. Decay and disease enter the heart of the tree through such unhealed wounds, which will remain unhealed until the stubs are sawed off or chiselled out. A stub so neglected, sticking out from and opening into the live tissue of the tree, may be compared to a thorn or a splinter embedded in and projecting from the flesh. Neither the skin of the body, nor the bark of the tree, can heal over their respective wounds; hence an avenue is laid open for the entrance of foreign particles into the interior of the organism.

Making all cuts flush, while the main problem of pruning, is not the only one. Care also must be taken to prevent the bark below the cut from tearing down when the limb drops off. Although small limbs may be cut off without any special precautions, large, heavy limbs demand special technique for the reason that their weight pulls them down when sawed only part way through, with the result that the bark, and sometimes part of the wood, tears down along the adjacent tissues of the trunk (or parent limb). On some groups of trees (elms, for instance), the bark tears much more easily than on others. On the Chinese elm, strips of bark 3 or 4 feet long may be torn down by incautious pruning. Such scars not only disfigure a tree but may do it serious harm by exposing large surfaces of wood to attack by fungi and insects.

There are several methods by which splitting or tearing down can be prevented. One is by undercutting the limb one-fourth or one-third of its thickness before beginning to cut from above. This procedure, practicable on small or medium-sized limbs, is harder to apply on large limbs because of the difficulty of sawing upwards with a heavy saw. Another method is by making a cut from each side in the form of the letter "V" with the apex at the bottom; this is actually a modified form of undercutting and in many cases may be found more convenient. A third method is by anchoring the limb with a rope tied near its center of gravity and passed over a limb above; this method has the advantage of simultaneously securing the limb for lowering and preventing splitting at the cut by not slacking off until the cut is finished. Still another and perhaps the safest method is by first cutting the limb off at a point 2 or 3 feet distant from the place where the final cut is to be made, after which, with the dangerous weight removed, the resultant stub may be cut off cleanly.

JUMP CUTS

A "jump cut" allows a limb to break off cleanly and suddenly. It is accomplished by sawing the limb one-half or one-third of the way through on the underside, then sawing in on the upper side one or two inches out and away from the under cut. When the upper cut reaches the lower cut, the intervening strip of wood breaks off sharply and cleanly, and the cut limb jumps away from the uncut portion out into space.

This is very useful in those cases where the limb has room to fall, avoiding the necessity of tying a rope on it. If the upper cut is made several inches *in* from the under cut, however, the limb instead of jumping will split downwards for a considerable distance, getting out of control and damaging other parts of the tree.

If the limb is sawed from one side only, it will, in some trees, break slowly and remain hanging from the bark and part of the sapwood, frequently becoming entangled with limbs farther down. In other trees it may break slowly, then let loose suddenly or otherwise behave unpredictably. There are, of course, occasions where it is desirable for a limb to break slowly.

LOWERING LIMBS

Cutting off limbs is one problem; getting them to the ground safely is another. In an open situation, with no obstacles beneath, most limbs can be allowed to fall freely; the larger, heavier limbs, however, should be let down with ropes because of the danger to workers and possible breakage of branches lower down. In working above a house, street, utility wires, or other damageable property, such as lawns, every sizable limb should be lowered by ropes. While considerable time is consumed in exercising this caution, it is time well spent, for a falling limb sometimes strikes and bounces in a way that not even an expert can foresee.

Large limbs should be tied with three ropes: one strong one tied near the center and passed through a crotch or over a limb above to sustain the weight, and two smaller lines fastened at each end to guide the limb free of wires, roofs, etc., as it is being lowered. Care should be taken to tie all knots properly and to use only strong, trustworthy rope; a slip or a break at the wrong time can be very costly. It is also wise not to have too many men working in the same tree, for if one is below or even to one side of another, he is working in constant danger. Always be sure that the crotch or limb above, which will support the bulk of the load, is strong enough for this purpose.

TIME TO PRUNE

The fact that pruning is still associated in the minds of many with topping has given rise to the idea that it should be done only when the tree is dormant. Many people refuse to have their trees worked on except during the winter months. It is true that a tree should not be radically topped when in full leaf, but dead wood can be removed any time and should be removed as soon as it is noticed. Similarly, live limbs can be removed any time, provided that they constitute a small per cent of the tree's total body. Tree pruners work every day of the year. In fact, pruning when the tree is in full leaf makes it easier to distinguish the live wood from the dead.

Studies show that pruning cuts made late in winter or early in the spring heal over more quickly than cuts made at other times, because they take advantage of the immediately following spring growth. However, rapidity of healing is not so important as the prevention of decay, and decay is prevented by proper wound dressing. Hence, theoretically, pruning may be done at any season of the year, and in practice it is so done.

Exceptions are made in the case of severe "bleeders," such as maples, birches, walnuts, and yellowwood, which bleed profusely if pruned when dormant or in early spring. These should be pruned only when in full leaf.

WOUND DRESSINGS

Painting pruning cuts, long considered indispensable, is at present a debated question. The rule formerly recommended and still practiced by most arborists is that all pruning cuts and other wounds over an inch in diameter should be covered with a good tree dressing. Smaller cuts heal over so rapidly that they need not be painted; moreover, in a large tree painting them is impractical.

However, there are those who contend that painting does more harm than good—that it retards callus development and interferes with the exudation of protective natural resins from cut surfaces.

Not enough evidence has yet been gathered to make the issue perfectly clear. While it is certain that some trees have protective resins, such as the pines and most other conifers, some do not have them and hence need protection. Even though unpainted wounds may heal over more rapidly, it is probably more important to exclude decay organisms by the application of paint.

The ideal tree paint should exclude decay organisms, be harmless to live tissue, promote healing, resist weathering, not interfere with natural exudations, be easily applied, and reasonably inexpensive. Such a material has not yet been formulated.

Of the many different substances used, *asphaltum mixtures* seem to be preferred at present. They weather well, are easily applied, and are made antiseptic by the addition of a special ingredient. Their disadvantage is that they are often made too thick, causing escaping sap and gas to form water blisters which break and leave exposed wood areas; also when too thick they seem to encourage decay rather than prevent it. They may be thinned with linseed oil.

Pine tar, used by veterinarians in the treatment of flesh wounds, is an excellent tree paint too little used. Its strong, clear odor is an additional recommendation.

Zinc oxide mixed in linseed oil has proved a fairly good paint. It retards decay and checking and is innocuous to the cambium, but does not weather as well as it might.

Creosote or other paints containing creosote should not be used. While an excellent preserver of dead wood, creosote is toxic to live tissues; hence it will injure the cambium at the edges of wounds and retard the growth of callus tissue. It may be used sparingly for the treatment of dead heartwood in cavities.

Tar preparations—not the same as asphalt—are not to be recommended because they form an impervious surface not allowing the escape of moisture in the wood; hence decay is stimulated, not checked.

Bordeaux mixture (copper sulphate) mixed in linseed oil is one of the most widely sold tree paints. Its normal color is blue green, although sometimes it is blackened by the addition of lampblack. Since it contains a very active fungicide, it is one of the best for preventing decay. Its chief disadvantage is that it flakes away very rapidly, needing to be re-applied every six months or so.

House paints (most of which contain oxides of lead) are not to be recommended because they injure the cambium unless previously protected with shellac.

Orange shellac, a specific for treating the edges of wounds to prevent drying out of the cambium, may sometimes be used as a dressing, particularly for small wounds. Its main disadvantage is its lack of durability.

Grafting waxes may be used for small wounds, although they should be thinned with alcohol.

Although paints are more easily and effectively applied when the pruning wounds are dry, in practice they are almost always applied soon after the cuts are made—the same day or at the most a few days later. Shellac, however, to be effective must be applied within fifteen minutes after tender tissues are exposed.

OLD WOUNDS

Large wounds, which heal over very slowly, should be periodically inspected and repainted. Where flaked or weathered, the old paint should be scraped off with a wire brush before applying the new. The ring of developing callus tissue should not be painted.

Old wounds which show enlarging cracks need special treatment, for these are open doors for wood-decaying fungi. Sometimes a heavy coating of asphalt will seal over the cracks. (If the wound is cracked, it is also dry; hence, heavy, impervious coatings will do no harm) Sometimes a piece of cloth painted with asphalt on both sides may be tacked over the surface. Sometimes a piece of tin cut to fit and painted on both sides may be tacked over the cut, taking care to tack it down very snugly around the edges and not to cover the developing callus tissue. Sometimes the whole area should be excavated to a depth of 2 or 3 inches and a concrete facing put in. (See chapter on Cavity Repair.)

METHOD OF APPLYING PAINT

Paint is usually carried in a tin can with a wire handle. Some tree workers tie the can to the short dangling end of their safety rope, carrying it about with them at all times and painting each cut as they make it. Others prefer to have the can sent up to them by the "rope elevator" whenever they are ready to use it. Others let it hang from the center of the tree on a rope, pulling it over to them by the pole saw as needed.

The advantage of painting cuts as made is that it saves double climbing. The disadvantage of carrying the paint can is that paint gets on the worker's hands and clothes, on the ropes, on the ladders, and on all the tools.

Another method of applying the paint is by paint poles. These are long poles, 10 or 12 feet long, on the end of which is tied a paint brush. The brush may simply be wired on or may be fitted into a slot cut in the pole. Best brushes are round ones with fairly stiff bristles and long handles. With the paint pole the worker can stand on the ground or on a step-ladder and reach most cuts on a small tree. He can also take it up in the tree to reach inaccessible cuts. By standing in the major forks of the tree, he can reach nearly all the cuts in the upper region, and by standing on the ground, he can reach the remaining ones. For very high cuts the pole can be fitted with an extension.

Advantages of the paint pole are that it makes the painting much more rapid and puts the paint on the pruning wounds rather than on the worker's clothes.

WIRE CLEARING

Wire clearing poses a special problem in pruning. Wire clearing means the removal of limbs that are touching, or about to touch, or in danger of falling on, telephone or power lines. Formerly this work was done by the telephone companies' and the light companies' own crews. More and more, however, these companies are contracting the work to tree expert organizations, partly because these can do the work faster and more efficiently and partly because they treat the trees with more consideration, thus avoiding difficulties with property owners, who justly protest against the mutilation of their trees by unskilled hands.

Thus the purposes of wire-clearing are two: (1) to keep the trees off the wires and (2) to damage the trees as little as possible. The wire-clearer should not forget his twofold obligation: toward the company that employs him and toward the homeowner on whose property he is often not welcome.

There are four types of wire-clearing: (1) topping, (2) side pruning, (3) drop-crotching, (4) directional pruning.

Topping, as the name indicates, shears off the whole top of a tree to prevent it from touching overhead wires. This treatment destroys the natural lines of a tree and consequently most of its beauty. Moreover, new shoots grow back so rapidly that cutting has to be repeated frequently. It is the method most commonly practiced by unskilled workers, particularly in small towns, where public opinion is less articulate in protest.

Side-pruning means the removal of large and small side branches on whatever side the wires go through. Since it leaves a gaping hole in the tree and forces it to grow to one side, it is no more recommended than topping.

Drop-crotching means the pruning back of large center branches to outward-pointing laterals, in an attempt to make a tree grow away from the wires. Although somewhat better than (1) and (2), its necessary cutting of large limbs opens up areas of possible decay.

Directional pruning is the best method of all, from the standpoint of the tree; also the one which requires the least follow-up. It involves the judicious removal of small branches in order to open up adequate but not excessively large paths for the wires through the trees; also the anticipation of future growth by the skillful pruning of neighboring branches away from the wires. It means the intelligent tailoring of the tree to the wires with benefit to the latter and no disfigurement to the former. Only an experienced tree worker is qualified to do this kind of pruning.

LIMBS OVER ROOFS

Special pruning problems are created by the proximity of trees to houses. Branches spread out and begin to rub against shingles; limbs break off in winds and knock holes in roofs; porches, wings, and entire houses are sometimes built around trees, with specially designed places in the roof for the accommodation of the trunk. One of the commonest activities of the tree expert is the removal of limbs in conflict with roofs and the removal of trees themselves from their roof apertures, when continuing growth has proved the impracticality of such design. It is good for neither tree nor house to attempt to fit the two together.

Special considerations need to be advanced in the cases where limbs overhang but the trunk is distant. Even though a tree may stand at a considerable distance from a house, its branches not infrequently grow over the roof. When kept within proper limits, branches over a roof contribute shade and beauty. Their disadvantages are that they present a certain danger in the event of breakage, and secondly, that they keep the gutters well filled with leaves. At no time should the branches be allowed to rest upon or scrape the roof, since in this contact both elements suffer. Holes are many times worn in roofs by scraping branches; the branches themselves are sometimes worn half or two-thirds of the way through. To prevent the branch tips from scraping, it is usually necessary to trim them back 4, 5, or 6 feet, since they move back and forth through large arcs during high winds.

Proper pruning over houses requires both knowledge and art in order to preserve the beauty of the tree and at the same time prevent damage to the roof. It does not mean the ugly barbarous stubbing off of major limbs at a point even with the roof edge. It means rather the proper flush-cutting of all smaller, downward-pointing branches that are touching or are likely to touch, to encourage the tree to grow upward away from the roof. The second danger, that of projecting limbs falling, may be obviated by skillful cabling.

Limbs which are correctly trimmed and cabled eliminate harm to roofs, unless one objects to the minor issue of leaves in the gutters, but even this can be prevented by screening the gutters, which is not a bad idea in any case. Incontestably, roofs, inherently ugly in spite of the best efforts of modern architects, are esthetically improved by the proximity of trees. Wide-spreading trees, such as certain of the oaks, can convert even the drabbest of roofs into a thing of interest.

FRUIT TREES

The pruning of fruit trees is in several respects different from the pruning of shade trees. Fruit trees are pruned primarily for the maximum production of fruit. Like the shade tree, they are also pruned for the removal of dead and diseased wood and are trained to a certain form, but these procedures are subservient to the main end: the production of fruit.

Since fruit trees are, of course, considerably smaller than shade trees, much of their pruning can be done from the ground or from five-foot stepladders. With the right tools and a little practice, the home-owner can do much toward maintaining his own trees.

In general, fruit trees are pruned to develop low heads and more or less open centers. The lowest limb should be 1½ or 2 feet above the ground. The next limb should appear 10 or 12 inches above this one and on the opposite side of the trunk, and the remaining main limbs should follow this staggered pattern. Weak double or triple crotches should be avoided by early training. Already existing weak crotches should be strengthened by braces.

A strong scaffolding should be the consistent aim in pruning. The development of lateral branches from main limbs should imitate the development of main limbs from the trunk. Weak, spindly branches and all overlapping and interwoven branches should be cut off. From its earliest age the trees should be trained toward the desired form. "As the twig is bent, so grows the tree."

On most fruit trees the center is kept fairly well open to allow light and air to reach all parts, thus preventing the development of fungus diseases and preserving the fruiting ability of lower limbs. Heads are kept low to make pruning, spraying, and harvesting easier.

Fruit spurs—short, wiry shoots along the main limbs of apples and pears—should not be cut off, as they may bear fruit for periods as long as ten years. However, longer, strictly vegetative shoots growing in the same area should be cut off.

For the production of fruit, not all trees are pruned alike, The apple is not pruned like the peach, nor the pear like the plum. Moreover, pruning practices vary from region to region, according to the climate and the soil. If you have fruit trees, you will do best to consult your county agent and follow the pruning techniques recommended for your region.

In general, peaches are pruned back severely all around the periphery when dormant; plums less so; cherries still less; pears and apples least of all. Long, rapidly growing vegetative branches are clipped off from time to time to divert growth energy into fruit production. Suckers or watersprouts are kept cut off for the same reason. Thinning of the small fruits is about as important as pruning: the sacrifice of some for the better development of others.

Severe pruning should be done in the dormant season only, preferably in late winter. The removal of dead limbs or a minor number of live ones can be done any time. Cuts should be protected with antiseptic paint.

TOOLS

Good pruning demands good tools. The lack of adequate tools defeats the amateur quite as much as the lack of practice. Carpenter saws, with their narrow set and small teeth, are meant for dry boards, rather than green limbs. Even most so-called pruning saws sold in hardware stores are inadequate: they have too much curve, and their teeth are improperly shaped and too small.

The correct pruning saw has large teeth, 4 or 5 to the inch, deep gullets to carry out the sawdust, and a wide set, so that it will not stick in green cuts. It must be kept very sharp, and from time to time the gullets need to be deepened, as the teeth wear down.

There are two main types of pruning saws: those that cut on the pull stroke and those that cut on the push stroke. Among veteran tree workers heated arguments are sometimes held concerning the superiority of one type over the other. Actually, each type has its advantages to such a degree that both are indispensable. The pull saw has its teeth slanted backwards towards the operator and its blade slightly curved. It cuts on the pull stroke, the curved blade making it feed itself without need of much down pressure. The pull saw is essential for reaching far up or far out, where much more force can be exerted by pulling than by pushing. It is particularly useful for mounting on poles, thus greatly extending the operator's reach. In fact, it is so much used on poles that it is called "pole saw" more than "pull saw."

The tree worker should have a variety of these saws, mounted on poles of different lengths: 4 feet, 6 feet, 8 feet, and 10 feet. In trees with dense centers the short-handled saws are the most maneuverable. In large, open trees even the ten-foot handles are too short.

The blades are easily mounted by sawing a slot in the exact center of one end of the pole, drilling two holes through pole and saw, and fastening with $^3/_{16}$-inch stove bolts. There is a certain angle at which the blade must be set for maximum cutting efficiency. Handles should be sanded and shellacked. A piece of cord passed through a hole in the other end of the handle is useful for hanging the saw on twigs.

The push saw is made with straight edge and teeth slanted away from the operator, like a carpenter's saw. It is effective in all cases where the operator can get above the limb to be cut, thus putting his weight into the downstroke.

In all conditions where it is easier to push than to pull, the push saw is obviously better. In all other cases the pull saw is to be preferred. Push saws are made in several lengths, the most useful being the short 20-inch, all-purpose saw and the 36-inch "bull saw," designed for cutting large limbs.

In addition to the saws, the tree worker needs a twig pruner. This is in essence a pair of cutting edges mounted on a pole and made to come together like shears by pulling on a cord. It is the tool made familiar to most of us by telephone and power linemen, who use it to cut overhanging limbs back from wires.

The twig-pruner should be mounted on a 10- or 12-foot pole, which in turn may be fitted with a similar length extension when needed. It is a very useful tool for heading back long, flexible branches and for cutting branch tips back from roofs and wires. It can be used to a certain extent for cutting small branches inside the tree, although its construction does not permit it to make perfectly flush cuts. A 1½-inch limb is about the largest that can be cut with a pruner. Since slender branch tips may be clipped off at any point without need of flush-cutting and since they are so movable that sawing them is nearly impossible, the pruner is the preferred tool for working at the tree's periphery.

IV

CAVITY REPAIR

CAVITY REPAIR is probably the most spectacular phase of tree work. The very fact that the whole science of tree care has come to be called "tree surgery" indicates that in common conception the chisel, gouge, and mallet have pre-empted the center of attention, and the part has given its name to the whole.

In spite of the interest it has commanded, cavity repair is perhaps that part of tree care least frequently performed correctly. Each cavity presents a different problem, each one has a different shape and size, each one is located in a different place. Only a thorough knowledge of the tree's structure and growth habits, implemented by practice under tutelage, will convert the apprentice into the expert.

By learning something about the theory and practice of cavity repair, the homeowner will find himself able to make many minor repairs, such as bark wounds and small cavities. Larger cavities, however, should be entrusted only to a trained arborist. But whether the owner does the work himself or watches it done, he will probably like to know the latest information on the subject. Certainly, an awareness of the problems involved will be of help to him during his consultation with the arborist.

What is a cavity? A cavity is any hole, large or small, which occurs in the sapwood or heartwood or both. A perfect tree presents an unbroken bark surface continuous from roots to twigs. Whenever the bark is skinned, cut, bruised, or burned in such a manner that the wood proper is exposed, the affected area becomes at once the site of a potential cavity. Bark wounds are not themselves cavities, but they often open the door to the development of cavities. In fact, were the bark surface to remain unbroken, no cavity could ever develop.

Wounds, then, are of two kinds: (1) bark wounds, involving the outer and inner bark, and (2) cavities, which involve decay of the sapwood or heartwood or both. In general cavities are more dangerous than bark wounds, since they originate in bark wounds and indicate deeper penetration of decay. However, a tree will die if its bark is knocked off or cut off in a continuous horizontal strip, even though it have no sapwood or heartwood decay. Under no circumstances should bark wounds be considered unimportant, since they not only open infection into the heart of the tree but they imperil the most vital part of the whole tree, the cambium layer itself.

The repair of bark wounds and cavities is facilitated by the fact that trees, like many other living organisms, have the power of regenerating lost parts. Wounds in trees heal much as do wounds in animals: by the formation of scar tissue. The difference is that in trees the growth of new tissue is only from the edges of the wound (where the living cambium is present) toward the center, the woody heart being inactive.

REPAIR OF BARK WOUNDS

The treatment of a bark wound is relatively simple. The bark edges around the damaged area should be cut back into the form of an ellipse with its long axis parallel to the direction of sap flow, and the exposed sapwood should be painted over with antiseptic tree paint. This procedure is often called *tracing.*

When the wound is so shaped, the healing-over process is accelerated, for the reason that the sap can flow much more easily around an ellipse than around a square corner, just as air flows more readily around a modern stream-lined car than around the old-fashioned box type. The edges of the bark can be cut into the desired shape with mallet and chisel or with an extremely sharp knife. Freshly cut bark edges should be covered with a coating of orange shellac to prevent drying out.

Painting of the exposed wood is necessary to prevent its decay before the bark manages to heal over. In large wounds the wood needs to be repainted every six months or every year, as the paint weathers off. Ordinary house paint is not a satisfactory dressing, nor are paints containing creosote or carbolineum, since these, although preservative of dead wood, are toxic to live tissue. Specially prepared tree paints are made with an asphalt base and contain antiseptic ingredients.

An ordinary pruning cut is of course a bark wound and should be painted over. Small pruning cuts are usually not shaped, but large cuts (8 inches or more across) should be pointed at the upper and lower edges.

PRINCIPLES AND PURPOSES OF CAVITY REPAIR

Treatment of cavities is much more complex because (1) decay may spread upward, sideways, and downward for considerable distances; (2) most of it is not visible from the outside; (3) the work of cleaning out and repairing must often be done from a small opening of living tissue which is easily injured by careless blows of mallet or chisel. Every cavity is different; each one is a challenge to the ingenuity of the surgeon.

Cavities originate from the exposure of the wood due to wounds, pruning cuts, broken-off limbs, insect ravages, fire, etc.; they enlarge as the exposed wood decays or is eaten by certain wood-boring insects. Wood decay, the principal agent in the aggravation and enlargement of cavities, is caused by various kinds of fungi, which grow best when supplied with abundant air and water. Exclusion of air and water means the retardation or complete stoppage of wood decay. Thus the chief purpose of cavity repair, although not the only purpose, is the prevention of decay by artifically rebuilding a protective surface at all points where decay has commenced.

Other purposes of cavity repair are (1) to provide a firm surface over which the new roll of callus tissue can grow and so to encourage rapid closing of wounds, (2) to strengthen the tree by internal bracing of the cavity, (3) to eliminate breeding places for roaches, mosquitoes, ants, and vermin of all kinds, (4) to improve the tree's appearance.

Cavity repair includes both the "open-cavity" and "closed-cavity" procedures. Both procedures are scientific; both are commendable, and each has its legitimate use. These procedures are supplementary, not mutually exclusive, as adherents of one or the other method have sometimes alleged. At times the open-cavity treatment is correct, at times the closed-cavity treatment, according to the nature of the problem. Not infrequently the methods may be combined in the same cavity; the lower half being treated as a "closed" cavity, the upper half as an "open" one.

Specifically, open-cavity procedure differs from closed-cavity procedure in that the cavity is left open or unfilled in the first case, whereas in closed-cavity treatment the cavity is filled with some solid material, such as cement, wood bricks, rubber strips, or various asphalt-sawdust preparations. In all other respects, the two procedures are exactly the same. The preparatory steps of cleaning out the cavity, bracing it, and pointing it, correspond point for point in both procedures. In open-cavity treatment only the final step, that of inserting the filler material, is omitted.

The advisability of using solid fillers has long been in question, and the development of the open-cavity method has occurred as a reaction against the abuse of heavy materials, particularly concrete, which have sometimes proved unsatisfactory. In general, the cavity is best left open in the following cases:

(1) When the cavity is very shallow and the exposed wood still sound.
(2) When the cavity has nearly healed over so that filling would necessitate reopening it, in which case more harm than good might be done.
(3) When the cavity is long and narrow and does not catch water.
(4) When the cavity is situated at a joint or limb subject to frequent movement in such a manner that the filler would crack or pull away from the edges.
(5) When the tree involved is in a declining condition and shows no promise of forming good callus layers.
(6) When the tree involved is of a short-lived or soft-wooded kind.
(7) When the tree involved does not, for any reason, justify the expense.

In all other cases cavities should be filled. Particularly, they should be filled when:

(1) They are large and deep and in a valuable tree.
(2) They are so located as to catch and hold water.

(3) They are in a crotch or at the ground line so that further decay may mean destruction of all or part of the tree.

TECHNIQUE OF CAVITY REPAIR

Specifically, the repair of cavities involves the following steps: (1) removing dead and badly diseased wood as far as possible, (2) correctly shaping the cavity at bark level, (3) painting the wood surfaces and shellacking the exposed cambium, (4) providing for drainage, (5) bracing the cavity, and (6) filling the cavity.

REMOVING DEAD AND BADLY DISEASED WOOD

It used to be taught that *all* diseased wood should be removed; and acting on this doctrine many a conscientious tree surgeon chiseled away, termite-like, at a tree's interior until the tree toppled over. It is now known to be impossible to remove all diseased wood, for the mycelial threads of the decay-producing fungi run many feet from the center of decay in all directions, invading even apparently sound wood. *Complete* eradication is mechanically impossible. Therefore, what should be done is to remove it only so far as practical. That means that the water-soaked and most badly diseased wood should be carefully cleaned away down to a reasonably sound surface of firm wood. In many trees, particularly in the oaks, layers of sound wood and layers of rotten wood may alternate through a space of a foot or more so that the attempt to remove the rotten wood means sacrificing the sound wood, the loss of which might well cause the tree to fall over.

It may be questioned that if part of the diseased wood is left, will not decay continue after the cavity is sealed over? Nature has given the answer to this by providing us with many examples of cavities that have healed over by themselves Examination of these cavities reveals that once the surface has healed over, internal decay is greatly retarded or completely arrested, even though pockets of water and decay organisms are sealed up inside.

The important thing, then, is to get out the worst of the decayed and punky wood and to establish an air-tight seal over the rest. In the case of open cavities, where no water is caught, no seal is attempted, the wood decaying very slowly or not at all because it is kept dry by exposure to the air.

In excavating diseased and dead wood, the tools used are hatchets, wood chisels, gouges, wooden mallet, various kinds of scrapers and smoothers, and a long-handled scoop or spoon used for pulling out the debris from the bottom of the pockets. Some of the larger companies use gouges run by compressed air, making the work much faster and easier.

All tools must be kept sharp, the difference between a sharp chisel and a dull one being as great as that between a sharp axe and a dull axe. Hatchets may be used to advantage where the cavity is large enough to permit. Near the edges of a wound, however, only chisel, gouge, and mallet should be used; and the greatest care should be exercised, for a chance blow of the mallet on the tender living tissues or a chance cut with the chisel or even an outward prying movement where the living edge serves as a fulcrum, will kill the tissue at that point and so cause new callus development to begin farther back.

Correctly Shaping the Cavity at Bark Level

This measure is as important as any of the others and should by no means be considered a secondary issue.

Correct shaping, as for simple bark wounds, means bringing the upper and lower edges of the cavity to a point, so that the completed cavity, as seen from the outside, looks more or less like an oval or ellipse with its longitudinal axis parallel with the direction of the trunk or limb If the limb grows at an angle of 45 degrees, the longitudinal axis of the cavity should tilt at precisely 45 degrees. If the limb grows straight outward at 90 degrees, the axis of the cavity should point to 90 degrees. If the limb curves upward or downward throughout its affected area, the cavity should follow it in its twistings.

The reason for this peculiarity is that, for rapid healing, the lines of the cavity should enter the current of sap flow in as streamlined a fashion as possible. Since sap flows lengthwise up and down a limb the lines of the cavity must accommodate themselves to this current, entering it gently, like a wedge, rather than intercepting it abruptly, like a barrier. If the bottom and/or top of a cavity is left square or even broadly round, the flow of sap (in the sapwood, cambium, and phloem) has great difficulty in making its way around these blunt corners. If, on the other hand, the top and bottom are shaped to a wedge-like point, the sap flows around the wound with ease.

(These remarks apply to the ouside of the wound, at bark level, where the healing callus tissue is to form. The inside of a cavity may be left in any shape, square, rectangular, or round, although for the sake of convenience it is generally cut to the same shape as the outside.)

PAINTING THE WOOD SURFACES AND SHELLACKING THE EXPOSED CAMBIUM

Once the cavity is excavated down to reasonably firm wood, these wood surfaces should be scraped and smoothed to the point where they will take a coat of paint. The paint should be applied liberally and allowed to dry before putting in the filler. It should have an asphalt base to make it waterproof and should contain a fungicide to discourage further decay. Creosote is an excellent wood preserver, although dangerous to use near living tissue to which it is toxic.

All of the interior of the cavity that can be reached with a brush should be painted; if it can be sprayed so much the better. Some arborists, not content with painting the wood, go so far as to tack roofing paper along the back and sides of the cavity to prevent the filler (usually concrete) from coming in contact with the wood. This helps to prevent further decay, since moisture often condenses on the inner face of a concrete filling.

A further elaboration is to cut veins into the back of the cavity, complete with midrib and lateral veins, in such a manner that any water accidentally entering will roll down the lateral veins into the midrib and down the midrib to the bottom of the cavity, from where it is conducted through a drain pipe to be discharged outside the tree.

How far to go in the way of these refinements depends on the value of the tree and the disposition of the owner. Obviously, the more care that is taken, the better protected the tree. However, in most cases, particularly in small cavities and in only moderately valuable trees, painting of the wood is precaution enough. Indeed, many workers fill without painting at all, relying on the tightness of the seal to arrest decay.

In case of the open cavity, use of antiseptic paint is doubly important. Such cavities have the advantage of being open to inspection at all times and being accessible for periodic repainting.

A supplement of painting is shellacking. Orange shellac, which may be purchased in any hardware or paint store, should be applied to all newly cut surfaces of bark and cambium. These tissues, which are usually cut into in the enlargement or final shaping of the cavity, are extremely tender, drying out and dying back for a distance of ½ to 1 inch from the edges of the cut. If, however, they are covered with shellac within five minutes or so after being exposed, they generally will not die back; hence new growth can start from that point instead of further back. Since it is desired that new callus tissue cover the edges of the cavity as soon as possible, obviously it is better for the cambium not to be allowed to die back.

Providing for Drainage

Since it is important that water should not stand in a cavity, a hole is bored at the bottom of the pocket, and a short length of copper drain pipe is installed. Such a hole serves to drain out any water present at the time of excavation and also to drain out any moisture entering subsequently.

To find the exact bottom of a cavity is sometimes difficult, for pockets of decay run sideways and diagonally at various angles. Probing instruments in the form of long, slender rods are run down the mouth of the cavity to attempt to locate the bottom. These measurements are then transferred to the outside, and a hole is bored toward the cavity at the estimated level. Sometimes several holes need to be bored, each one a little farther down, before the bottom of the pocket can be located. When the bit brings out only sound wood, one may be sure that the cavity has ended and that the next hole above is the true bottom.

Many times it is helpful to flush out a cavity with a garden hose with a high-pressure nozzle. The quantity of muck that can thus be flushed out of the drainage holes is astonishing. During the flushing operation the hole (or holes) should be reopened from time to time with the bit or with the probe to prevent clogging up.

The drain pipe should be slightly larger than the hole so that it may be driven in tightly. It needs to enter the sapwood only a short distance, an inch or an inch and a half, since the hole will never close together on the inside. The hole should enter the tree slanting slightly upward, so that the drain pipe may slant downward. The pipe should protrude from the tree 5 or 6 inches so that its drip will not run down the bark, discoloring and often injuring it. Protruding drain pipes close to the ground may be dangerous for children playing nearby. In this case they should be shortened or covered in some way.

Copper is considered the best material, although sections of ordinary iron water pipes are often used as well.

In case a cavity has several diverging pockets, a drain pipe should be installed at the bottom of each

BRACING THE CAVITY

Small cavities in sound wood need no bracing. Even large cavities, if surrounded by four or five inches of strong, healthy sapwood, rarely need bracing. But in many cavities decay has progressed so far that the surrounding shell of sapwood often measures less than four inches; sometimes only two inches or less, indeed at some points decay bursts quite through the shell so that the cavity comes to have two, three, or more mouths.

In such cases some kind of internal bracing is indispensable for two reasons: (1) to help keep the tree from breaking at that point, and (2) to prevent the walls of the cavity from pulling away from the filling. If, of course, decay has eaten too far into a tree, particularly into the trunk, the tree might better be cut down. But if there seems to be a reasonably sound shell left, then bracing, filling, and fertilizing will do much toward saving the tree.

It is impossible to define exactly the conditions under which a cavity should be braced. Much depends on the kind of tree, the shape and size of the cavity, and the location of the cavity. Some trees (such as oak) are much stronger than others (such as box elder). A three-inch shell in an oak might be strong enough to make bracing unnecessary, even though the whole heart were gone; while a five-inch shell in a box elder would hardly warrant confidence, braced or unbraced. Again, a long, narrow cavity seldom needs bracing, being naturally strong and healing over very rapidly, while a wide, deep cavity almost always should be braced because of its tendency to open up farther and its slowness to heal. A cavity in a major crotch, even though only medium-sized, should definitely be braced because of the great strain to which the crotch is continually subject. Moreover, supplementary braces in the form of cables (see chapter on Cabling) should be installed at a point above the crotch.

Internal cavity bracing may be done in several ways:

(1) If the surrounding sapwood is strong enough and thick enough, lag screw hooks may be installed, connected with short lengths of galvanized cable, and drawn tight with a turnbuckle. Only in a large cavity will there be space enough to effect such an installation.

(2) If the sapwood shell is too thin to permit the use of lag screw hooks, or if the cavity is not large enough to allow working inside it, a hole may be bored from the outside entirely through the tree, and bolt and nut installed. Both the head-end and the nut-end of the bolt should be fitted with oval-shaped washers, and these should be countersunk below the bark surface so that scar tissue may cover them. By adjusting the nut the walls of the cavity can be prevented from buckling outward.

(3) Instead of bolt and nut, the threaded rod may be used. This is an untapered rod threaded along its entire length. It is screwed in one side of the tree until it begins to emerge from the other; the protruding end is then cut off. The rod does not need to be countersunk or measured ahead of time. Its disadvantage is that, while holding tight enough, it does not draw up.

Whichever type of brace is used, the principles involved are the same. Short cavities may demand one brace; long cavities two or more. Braces are installed transversely (but not necessarily in the same plane), sometimes diagonally, rarely longitudinally.

Filling the Cavity

If the cavity has been properly excavated and shaped, its filling is not so difficult as it might seem. The cavity should be, and usually is, larger on the inside than on the outside. In such cases, the filling will obviously stay put. On this same principle a dentist drills away at a tooth: to make the inner pocket larger than the surface opening. Where the mouth of the cavity is larger than the interior, the latter should be studded with large-headed shingle tacks, to help hold the filling in place.

The essentials of installing a filling are these:

(1) To put the filling in tightly in such a way that it will not fall out or be forced out by subsequent growth of the tree.
(2) To make a perfectly airtight and watertight seal at all points.
(3) To bring the face of the filling out (radially) to a point flush, or nearly flush with, the cambium layer in the edge of the surrounding wood shell. If the filling is carried outward past this point—flush with the outermost bark surface, for example, as is common in amateur operations—more harm than good is done, for the all-important cambium layer is then plastered over and kept from growing.
(4) To carry the edges of the filling (laterally) to a point within ⅛ of an inch of the live cambium in the surrounding shell. If greater distance is left between the edge of the filler and the edge of the cambium, the intervening sapwood, even though sound at the time of filling, will often decay or develop cracks that allow air and water to enter behind the filling.

Sometimes in a large wound, particularly a large pruning scar, only the center is decayed, the enveloping sapwood being sound and hard. In such cases the natural tendency is to excavate only the decayed center and to put the filling in this area. Such a procedure is of little value, however, for almost always the sapwood between the edge of the filler and the margin of live tissue decays before this latter can grow over it. The wider the area of sapwood left the longer it takes the callus tissue to cover it and the greater its probabilities of decaying.

Hence there is need to remove even sound tissue (at face of cavity, for at least a depth of 1½ inches) in order that the edge of the filler may be brought into proximity with the edge of the live cambium. When only ⅛ or ¼ of an inch separates the cambium from the filler the former is sure to grow over the edge of the latter during the first season. This is precisely the thing desired: once the new callus tissue has managed to grow over the edge of the filler all around its periphery, even though ever so little, an air-tight seal is secured, and the success of the cavity is assured. Thereafter it does not matter whether the scar tissue delays two years, three, five, ten, or fifty, in growing entirely together over the filling. It may grow as slowly as it likes, for the tree now presents one unbroken surface to the environment through which neither insects, fungi, air, nor water, can pass.

What is the best kind of filler? This is a question not yet answered. Almost every conceivable kind of material has been used: wooden blocks, rubber strips, asphalt and sawdust preparations, magnesite compounds, concrete, etc. A very early treatise on the subject (in the time of George III of England) recommends a mixture of lime, rubbish, sand, wood ashes, and cow manure. In the pioneer days of tree surgery in our country, sheets of tin or zinc were nailed over cavities. Even plaster of paris has been used, molded around wire mesh. Temporary coverings include sections of roofing paper, sheets of cardboard, wooden slats, split-open oil cans, and old mail-order catalogues.

The perfect filler should be quickly and easily installable, light in weight, strong and durable, semiflexible, resistant to insect invasions, waterproof and unaffected by heat and cold. Such a material has not yet been discovered, although some of the magnesium or magnesite compounds approximate the ideal very closely.

At the present time, despite its disadvantages, concrete continues to be the most widely used filler of all. Its advantages are these: (1) it can be manufactured at any given place and in any desired quantity; (2) its mixing requires no particular skill, no heating, no waiting to cool; (3) it is inexpensive; (4) when mixed as dry as possible, it can be pressed and patted into every kind of corner without falling or slumping; (5) it hardens quickly into the desired form; (6) it is permanent; (7) when properly smoothed and painted, it is highly presentable.

Its disadvantages are these: (1) it is inflexible, not accommodating itself to movements of the surrounding shell, hence violent movement of a filled limb (or trunk) may crack the concrete or break the limb (or trunk) at that point; (2) it is heavy, adding undesirable weight to a weakened part; (3) it expands and contracts at a different rate from that of the surrounding wood; hence cracks tend to open up at the region where the two substances join; (4) it is cold, so that moisture often condenses on its inner face.

Judged by popularity of use, the advantages of concrete continue to outweigh its disadvantages, most of which can be overcome by judicious supplementary measures. It is best used in small cavities or in cavities near the ground, where there is little or no movement. Cavities of any size high up in a tree where swaying of limbs or trunk is expected should be strongly braced internally to prevent the edge of the wood from pulling away from the concrete.

Since this is the material most widely used, the following method of application refers specifically to it.

Two parts of sand are mixed dry with one part of cement in the quantity desired. When thoroughly mixed, water is added a little at a time while the mixing is continued. (For small quantities a mortar board and a mason's trowel are sufficient. Larger quantities may be mixed in a wheelbarrow with a hoe.) When the mixture reaches the point where a ball of it kneaded with the hands will just hold together, it is ready for use. In this condition the mixture is considered "dry." The error of the beginner is to make the mixture too wet, in which condition it will run out of all cavities (except those with their mouths uppermost) as fast as put in. But when "dry," it can be molded with the hands, like putty or plastic wood, and made to fit into all corners and follow all curves.

As the mixture is placed in the cavity (with trowel, scoop, or hands), it should be pressed into the corners and tamped thoroughly, particularly around the edges. In cavities more than 8-10 inches long or wide, the mixture should be arranged in the form of bricks. This is accomplished by inserting strips of heavy roofing paper at intervals of 4 or 5 inches perpendicular to the face of the cavity, both horizontally and vertically so as to produce the effect of bricks joined by mortar. The strips should be placed with their outer edge slightly lower than their inner edge in such a manner that water will not enter through these joints. The strips (often called "section dividers") may be put in place as the filling is built up, or may be put in after all the filling has been completed, by scoring its face with the point of the trowel to the desired depth. The purpose of the section dividers is to provide expansion joints and a certain amount of play so that the concrete will not crack with changes in temperature and with movement. In addition, the brick design is more attractive than a solid concrete slab.

After the concrete is thoroughly tamped and pressed in and the section dividers are in place, the face of the filling is smoothed by use of a small trowel or a so-called "cavity slick." This last is a specially designed, miniature trowel, flat and pointed on one end and rounded like a spoon on the other—a very handy tool for smoothing and pressing the largest or the smallest filling. However dry the mixture may seem to be, moisture will ooze out of it when polished with the cavity slick, and a smooth, slick finish will be obtained.

When the concrete is mixed as described, it may be put into nearly all cavities, whether they face upward, sideways, or downward, without the use of forms. In the case of very wide cavities facing directly downward, however, some difficulty may be experienced. On such occasions, boards may have to be tacked or tied temporarily over the cavity to hold the filling in place. Another solution is to use a piece of heavy screen wire or wire mesh, the edges of which may be placed within the cavity, while the mixture is inserted through the ends or through an opening cut for the purpose. After the concrete hardens, the wire may be left in place and covered up by an additional thin layer of cement, although in such cases the use of section dividers is eliminated.

Small cavities may be filled solidly. Larger cavities, particularly deep ones, need not be so filled; indeed a great heavy mass of concrete only adds unnecessary weight and comes into contact with the wood at unnecessary points. Contrary to general belief, concrete in a tree does not make it stronger; it may in fact make it weaker by providing a fulcrum on which the tree may break apart.

In case of a deep cavity, let us say one of more than six inches' depth, solid fillings are not so much to be recommended as the so-called "facing." The *facing* is a concrete filling [illegible] thick built up across the mouth of the cavity, exactly as described above, but supported at the back by a platform of boards wedged and nailed in for that purpose. Thus the rear face of the filling, instead of resting against the inside of the cavity, rests against the board backing, the distance between the boards and the interior face of the cavity being by this means converted into a dead-air space.

This arrangement has the virtue of bringing the concrete into contact with the tree only around its edges and of reducing considerably the added weight. It also makes drainage easier and provides a means for subsequent spraying and disinfection of the interior of the cavity (through the drain pipe), if this should be necessary.

The board backing must be very securely put in place; otherwise the pressure exerted on the concrete by the slowly advancing scar tissue will dislodge it. The boards should be of good, sound wood, painted, and firmly nailed together against supporting back cross-pieces. The ends of the boards should be inserted in grooves cut in the tree's sound sapwood. If the cavity has internal brace-rods (as it should have if large and deep), the backing may conveniently rest against these. Wedged-in rocks also make a good backing for the concrete; in some cases a better backing than boards.

The completed filling may be painted black for the sake of appearance. Some of the asphalt-base tree paints are suitable for this purpose if mixed with linseed oil, which thins and imparts luster at the same time. A further refinement is to bevel slightly the edges of the concrete at the point where they join the section dividers, thus enhancing the bricklike effect.

TIN FACING FOR SPECIAL CASES

Where only the center of a large wound or large [illegible] is decayed and the surrounding wood is, although [illegible] and hard so that its excavation seems [illegible], the writer has developed an unorthodox method of [illegible], tried [illegible] on a variety of trees. [illegible]

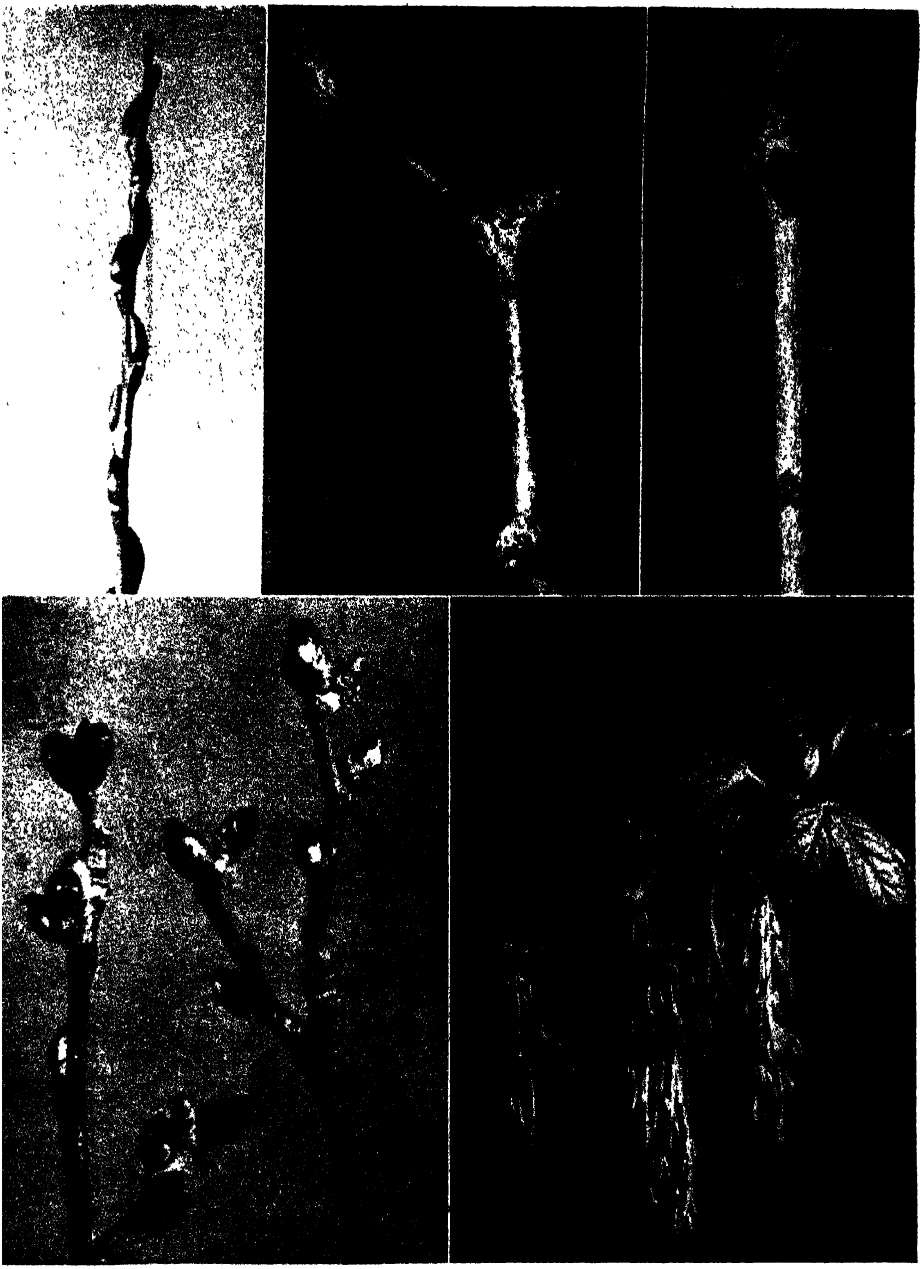

Plate 7. WINTER BUDS AND SPRING GROWTH. *Above:* Pussy willow, with a single, smooth covering scale; jujube, with rough bud coats, and post oak, with imbricated scales. *Below:* Silver-leaf poplar, with miniature leaves and flowers together in the buds, and box-elder with leaves issuing from terminal buds, flower clusters from lateral.

Plate 8. Men working in a tree. Supported by ropes, they can go to the very ends of the branches. Even without ropes (as in this picture) a skilled climber can do the same, although he is flirting with danger.

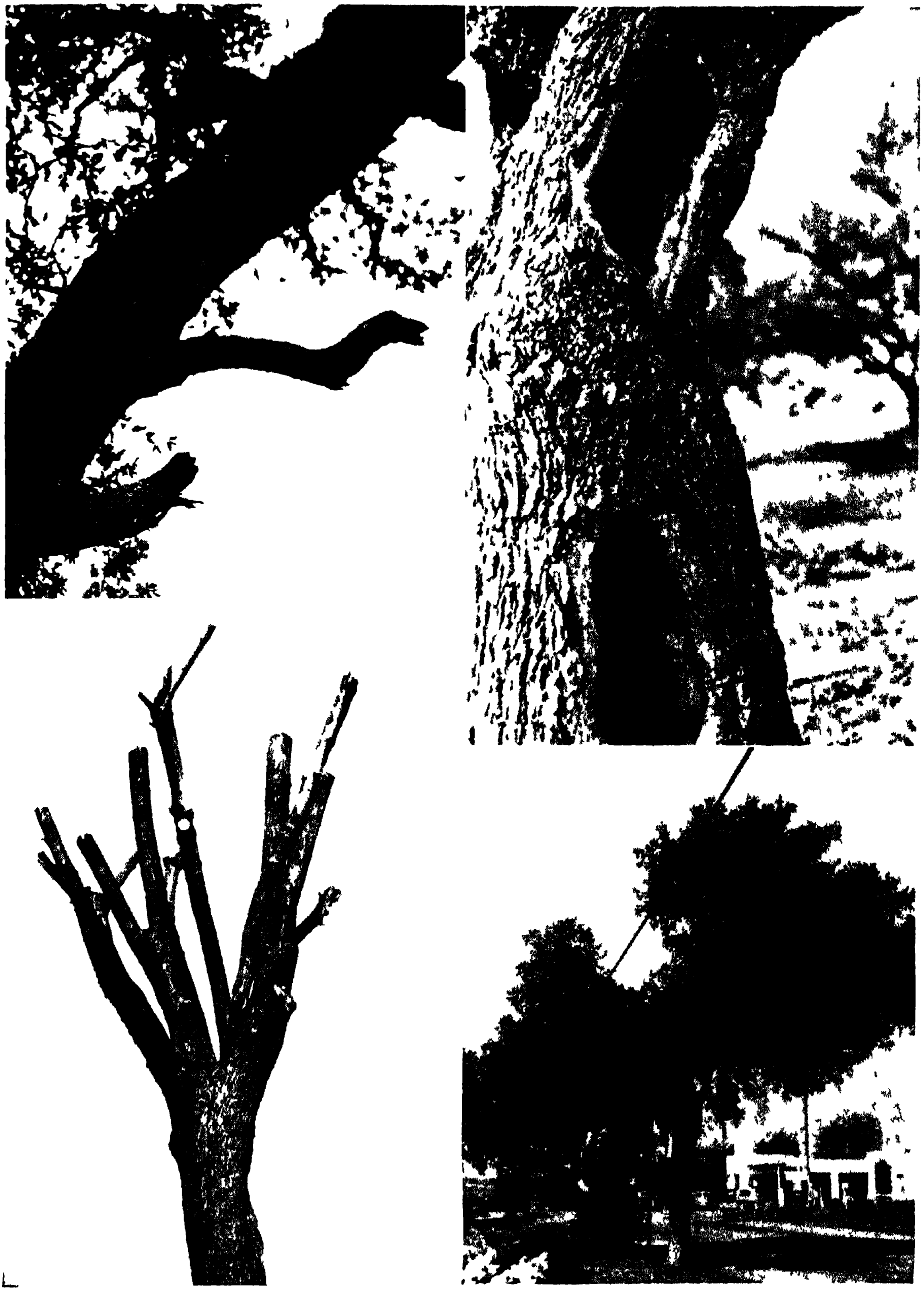

Plate 9 NEEDLESS DAMAGE *Above* Broken stubs (*left*) often cause cavities (*right*) which expose the living tree to insects and diseases Stubs cut flush allow the wound to heal *Lower left* Such mutilation is permissible only rarely. *Lower right* Improper line clearance destroys symmetry.

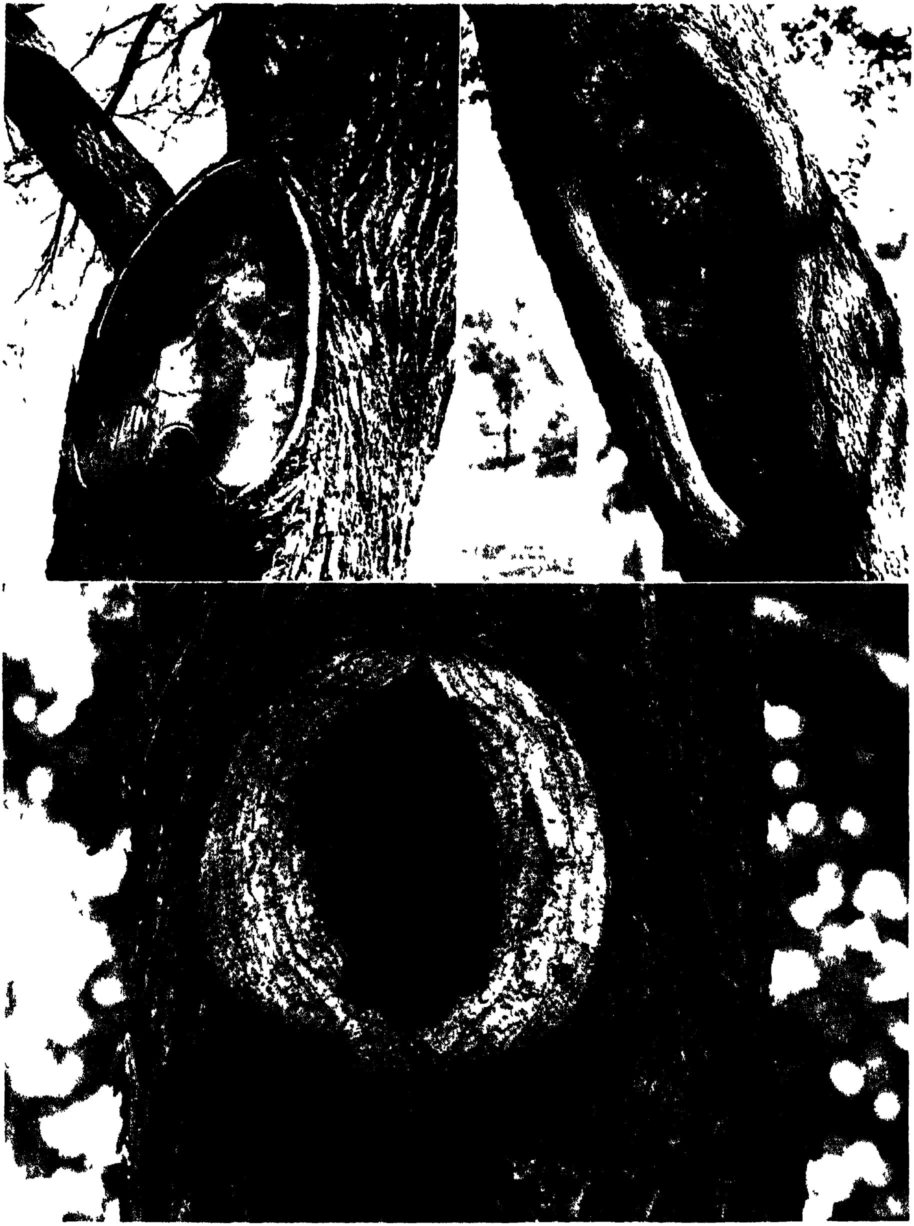

Plate 10. CARE OF TREE WOUNDS. *Above:* Two old pruning cuts in need of facing (see page 59). In so large a wound, decay spreads faster than the new callus unless it is checked. Wounds with pointed bases heal more rapidly, as at right. *Below:* A properly made pruning cut in the process of healing. The grayish area is new callus tissue. The dark center is exposed sapwood, protected by systematic painting.

the decayed center and either filling or not [illegible] condition demands; (b) painting the intervening [illegible] edge of the cavity and the surrounding callus tissue; [illegible] entire area with a piece of galvanized roofing tin, [illegible] tree paint on both sides, cut to the exact size and shape of the area, and tacked in place by a series of closely placed nails around its periphery, so that at no point is there more than [illegible] of exposed wood between the edge of the tin and the live callus tissue. The tin should be thick enough to withstand the elements but not so thick as to be difficult to cut and handle. A very good size is $\frac{1}{64}$ inch (No. 28 gauge in tinner's cant). It can be bought in large sheets and cut into the desired shape on the spot by the aid of tinner's shears and a paper template, which if fitted over the affected area first will readily determine the size and shape.

This method of treating cavities (in cases, it will be remembered, where only the center is decayed and the surrounding wood is still sound) is not practiced by the large tree surgery companies. Nevertheless, it offers some striking advantages—namely, (1) it is quickly and easily accomplished and hence is much less expensive than the concrete fillings; (2) it leaves intact large areas of sound wood which are often necessary to the tree for support (concrete does not add strength to a tree); (3) it prevents further decay and furnishes a base for new callus tissue quite as effectively as a concrete facing can do, for when tacked securely into place and carried out to the very edge of the wound, it is as quickly grown over as concrete or any other substance. Once the callus tissue has grown over its margins, it is 100 per cent airtight and watertight. It will never pull out or be dislodged or crushed. Being galvanized and painted, it will not rust or deteriorate in any way. It will not crack, like concrete, nor does it need to be laid in sections; moreover, water will not condense on its inner face. The wood and the cavity behind it are as well, if not better protected, as by any other kind of filler.

ADVICE TO HOMEOWNERS

Consider carefully the value of a tree before undertaking extensive cavity repair on it. If your tree is old, in a declining condition, or [illegible] particularly desirable, you would [illegible] better to remove it and plant a young, thrifty tree instead of spending money on expensive cavity repair.

On the other hand, small cavities even on old trees are profitably repaired, particularly if the tree is otherwise in good health. Very large cavities may be repaired if the tree is (1) valuable intrinsically, historically, or sentimentally; (2) vigorous enough to be able to callus over the filling, at least in part; (3) in no danger of falling over or breaking off at the point of decay.

The most important thing you can do is to prevent the development of cavities by proper pruning and to prevent the enlargement of existing small cavities by their prompt repair.

Do not attempt to repair the cavities yourself, except the smallest and most easily accessible. Do not deal with itinerant door-knockers, who are here today and gone tomorrow. Deal only with a reputable arborist and get his written declaration of what he proposes to do, the approximate cost of doing it, and the dates on which he will return to make inspection.

Because they are comparatively short-lived or weak-wooded, the following trees should not be subjected to extensive cavity filling:

Black Locust
Boxwood
Chinaberry
Crape Myrtle
Dogwoods
Lombardy Poplar
Magnolias
Mountain Ash
Ornamental Cherries
Panicled Goldenrain Tree
Paper Mulberry
Peaches
Plums
Redbud
White Birches
Yellowwood

Cavity filling should be undertaken on the following trees only if they are in exceptional health otherwise:

Apples
Black Oaks
Box Elder
Catalpa
Chinese Elm
Poplars
Royal Paulownia
Silver Maple
Tree of Heaven
Willows

V

CABLING AND BRACING

QUITE COMMONLY occasions arise where a tree needs some kind of mechanical support. This may be (1) for the trunk itself, when it is threatening to fall over, or rubbing against a house, or growing in some undesirable direction; or it may be (2) for a split crotch, either down the central axis of the tree trunk or higher up among the branches, or it may be (3) to hold up a limb hanging down too low, or rubbing on a roof or a wire, or in danger of breaking. Special types of braces have been developed for all these cases and for all variants of them. As simple as it may seem, bracing actually calls for a certain amount of engineering skill plus a knowledge of the structure and growing habits of trees. Although many braces are mechanically correct, they prove harmful because installed without regard to the tree's future growth.

In small and medium-sized trees the homeowner will have no difficulty installing braces and cables, once he has grasped the principle. In larger trees, however, where the climbing becomes too difficult, or where special equipment is needed, he will do better to call for a professional worker. In any case, he probably will find an account of the details of installation helpful and interesting.

Braces are divided into two general types: flexible and inflexible. Flexible braces are cables (formerly chains) which become rigid only when pull is being exerted upon them and hence allow a certain amount of freedom of movement to the parts which they support. Inflexible braces are screw rods or bolts and nuts, whose purpose is to bind together firmly and permanently certain parts where no movement is desirable. There is one more type, the vertical rigid brace, in the form of a wooden, concrete, or metal post, but this is used only as a last resort where bracing from above is not practicable.

FLEXIBLE BRACES

Flexible cable bracing has many uses: (1) *To raise* a low-hanging or sagging limb (2) To support from above any limb potentially dangerous (3) To support in a semi-rigid condition any limb that is in a position to sweep back and forth across a roof or to beat against a chimney, or to harm any other object (4) To secure all major limbs in valuable trees so as to prevent breakage during high winds or ice storms.

Cabling is strictly a preventive measure, of the kind whose ounces are worth many pounds of cure. A tree whose limbs are properly cabled together will withstand without loss of a limb the storms which leave its fellows broken and deformed. Relatively inexpensive, cabling is the wisest expenditure the homeowner can make on his trees. By comparison with the amount of pruning, tracing, and cavity work necessary to repair a storm-damaged tree, cabling is a very slight operation indeed. Prevention is always slight, just as repair is always costly. Cabling is something done before the storm strikes; pruning (in this sense) is something done after the storm passes.

There are a number of factors to be considered in the installation of cables. One is the method of attachment of the cable to the limb; another the optimum point on the limb at which attachment should be made; another the manner of tightening or loosening the cable, another, the kind of material to be used. Let us discuss these in order.

Cables should never be wrapped around limbs (or trunk), for as the tree grows in girth, it will inevitably push against the encircling cable and force it to cut into the bark, always injuring, sometimes killing, the tree. The use of rubber hoses, wooden slats, and other material inserted between cable and tree for the purpose of serving as shock absorbers (or better, pressure absorbers) only postpones the cutting action but does not eliminate it.

The only correct way to attach cables is by drilling a hole in the tree and inserting a lag screw hook, to which the cable is easily spliced or clamped. The size of the screw hook is in direct relation to the size of the limb in question; a very large hook would obviously be out of place in a very small limb, which it would split and weaken. When properly sized, the hook does no harm to the tree, touching it at one point only, like a nail.

Holes are predrilled, on the same principle that obtains in the use of screws in furniture. The hole should be slightly smaller than the hook, so that the latter may be screwed in firmly. If the hole is too large, the hook will be loose and insecure; if too small, the greatest difficulty will be found in inserting the hook, which will twist in two rather than enter too small a hole. Much depends on the kind of tree: in very soft woods, as box elder, willow, chinaberry, the hole may be and should be smaller than in hard woods, as oak, elm, or hickory. The whole point, of course, is to secure a firm fit between hook and tree. The hook does not pass entirely through the limb. Half or two-thirds of the limb's diameter is ordinarily sufficient, and the hole should be drilled no deeper than the hook's estimated reach. When the hook is ready to be inserted into the hole, it should be coated with tree paint along its shank to prevent possible entrance of fungi or insects.

Many people distrust the holding power of a lag screw hook; but if properly installed, it will never pull out. In fact, each year that passes adds to its strength, as the tree begins to form layers of new wood around it and gradually engulfs it. However, in cases where some extra heavy stress is foreseen or where a very weak-wooded tree is concerned, the eye-bolt may be substituted for the screw hook. The eye-bolt has the advantage of being secured on the other side by a nut, but it has the disadvantage of creating a hole entirely through the limb and hence weakening it a little. If the eye-bolt is used, the nut should be seated against an oval-shaped washer and countersunk beneath the bark level so as to allow callus tissue to form over the hole.

Whether lag screw or eye bolt is used, the principles involved are the same. The points to be observed are (1) that the fastener (screw or bolt) enter firmly in good, sound wood (2) that it be proportioned to the size of the limb concerned (3) that, while several cables may be attached to the same limb, the fasteners be placed a foot or so distant from each other, never directly opposite or contiguous (4) that the fastener be so placed that its length will be parallel with the direction of pull. So placed, the fastener will seem to be a continuation of the cable itself and will withstand the maximum pull, whereas if the fastener is placed where the pull is sideways to it, it may more easily bend or break.

Some lag screw hooks come with a small hole drilled in them at a point near the top of the hook. This hole is intended for the accommodation of a nail, which is passed through it and driven into the tree, after the cable has been spliced around the hook, thus preventing the looped end of the cable from jumping out of the hook in the case of sudden slackness along the cable. The nail thus serves as a safety lock, exactly like a cotter key through the drilled end of a bolt.

In case undrilled screw hooks are used, another way to lock the cable in securely is by simply screwing the hook down to the point where its open end touches the tree. In cases where the loop and splice are made on the spot with the hook already in place, no difficulties will be encountered. In places where it is more convenient to make the loop and splice on the ground, the hook may be screwed down to within a quarter turn or so of its final position (so that it remains open) and left so until the loop is ready; the loop may then be slipped over the hook and the latter given its last quarter of a turn to bring it against the tree and close the cable's channel of escape.

The proper point along the limbs to install the cable depends on various factors, such as the objective desired, the kind of tree, the shape of the tree, and the form and situation of the individual limbs involved. In general, limbs are cabled together on the principle of opposing forces. If one limb goes to the right and the other to the left, a cable connecting them will support both. If the cable is placed too far down on the limbs, the upper portions will possibly retain enough play to cause them to snap off precisely at the point where they are cabled. If the cable is placed too high, insufficient play will be allowed, and the lower, heavier parts of the limbs will remain practically unsupported. The optimum point is approximately half or two-thirds of the way along the limbs' length counting from the bottom up. This may be taken as a safe approximation, although only practice will enable one to judge skillfully.

In selecting the point, it should not be forgotten that the tree will continue to grow at the tips, so that a limb which extends only 10 feet above the cable today may extend 20 feet above it in 10 years. Cables installed on young trees are rapidly outgrown and need to be relocated from time to time. When a cable is to be moved, it should be unspliced or cut loose from its fastener; the fastener itself should never be unscrewed or dug out, since in nearly all cases the tree will have grown around it to the extent that removal will create an unnecessary wound.

After one end of the cable is fitted over the screw hook, the cable is stretched across to the location of the other hook, measured, and cut off with a liberal allowance for making the second splice. If the measure is exact, as it should be, certain difficulties will be encountered in passing the second loop over the second hook, for if it passes over it too easily, this means that the cable will be slack. Extreme slackness in a cable is undesirable, since it looks bad, and the cable does not function until great strain has separated the cabled members. Extreme tautness of cable is also undesirable because it does not permit any play between limbs and because a cable under strain at all times soon loses its elasticity and may be more easily broken in times of stress. A cable properly installed is left very slightly slack,[1] ready to catch and hold during emergency but not in a state of constant tension.

There are several methods of fitting the cable so that the desired tension will be obtained. One is by drawing the limbs together with a rope (using block and tackle, or pulling with a truck) until the second loop may be passed over its hook. When the rope is released, the limbs will return to their normal positions, and the cable will tighten up. With a little practice, one has no difficulty estimating the amount of tension desired.

Another method, better in some cases, is to insert a turnbuckle between cable and hook. The turnbuckle is opened to its widest, the other adjustments are made as close as possible, and the turnbuckle is then screwed down until the desired tension is reached. One disadvantage of turnbuckles is that they are not nearly so strong as they appear, according to their size, and that they are unsafe, therefore, in situations where heavy limbs are involved. In the writer's experience some have opened at the eyes, and others have cracked along the shaft. Small turnbuckles are acceptable for small limbs, but one strong enough for a really heavy limb would be so large as to be unsightly. For most purposes, the turnbuckle may be omitted. Installation is faster and more economical without it, and the connection safer. One argument in the turnbuckle's favor is that it makes possible an adjustment of tension as the future growth of the tree may demand. The same result may be obtained by leaving two feet or so of extra length at one end of the cable, and securing that end with two cable clamps in place of the splice. At any given time the clamps may easily be loosened and the cable tightened or slackened.

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[1] Except where a limb needs to be lifted and continuously held out of its normal position; in such cases the cable obviously must be taut.

An ingenious method of tightening the cable with only a pair of pliers was invented by John Paul Diaz. The cable is fastened permanently at one end, then pulled by hand as tight as possible through the hook on the other limb and formed into a loop. The cable is removed from the hook, and another loop formed in it about two inches back (toward the fastened end) from the first loop, which is then straightened out. A thimble[2] is slipped over the hook, the free end of the cable is passed through the hook and over the thimble and is then pulled suddenly and strongly so that the loop (now become a half-loop or bend) will come into the desired position around the hook. Where pulling by hand is not sufficient to accomplish this, the thimble and the cable lying in it are grabbed by the side-nosed pliers and forced by leverage against the hook itself into the correct position, where they are held with one hand until the other hand can begin the splicing operation. Although this explanation seems complicated, particularly to one not familiar with the materials involved, the procedure is really quite simple, and once performed cannot be forgotten. By this means, without block-and-tackle, coffin hoist, turnbuckle, or any other cumbersome and time-consuming devices, any cable, even a very long one, can be fitted as tightly and snugly as desired.

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[2] An ovoid piece of metal made with a shallow channel on the outer side into which the cable fits.

It is almost unnecessary to say that only the best materials should be used in cabling. Where the protection of the tree itself and of property and persons underneath are all involved, it would be as unforgivable to use inferior materials as it would be to make a careless installation. The fasteners (lag screw hooks or eye-bolts) should be strong, galvanized stock, of a size proportioned to the limb to which they are to be attached and to the amount of strain likely to be placed on them. They should be obtained from regular tree-supply manufacturers. (See chapter on Tools and Equipment.) Ordinary screw hooks, porch-swing hooks, and other standard hardware items are not adequate as cable fasteners, for they are too short, and their hooks are not shaped right.

A screw hook intended specifically for tree use has an extra long shank, threaded along its whole length, and a very strong, flattened hook. The shanks of all hooks, bolts, or other fasteners should be dipped in tree paint before being screwed into place. This helps prevent infection at the point of the artificial wound.

The cable itself is also a special kind, strong, flexible, and galvanized. The cable used by telephone and power companies, while strong enough, is too stiff to permit splicing and easy handling. Similarly, ungalvanized wire rope should never be used because it is too springy and because it rusts. Homemade cables, consisting of strands of wire twisted together with a stick, are seldom strong enough. Chains are too ponderous, too unsightly, and too expensive. Regular tree cable is a special product, of five or seven strands, obtainable in nearly any thickness, and suited exactly to the job.

At the point where the cable is looped over the hook it is advisable to use a thimble. The purpose of the thimble is to insure a gradual, rather than an acute, bending of the cable. Just as one may more safely double a water pipe by bending it over a barrel instead of bending it sharply at one point, so the cable should not be bent sharply around the hook. Bending the cable around the thimble by splicing it back up on itself also makes possible an open loop, which may easily be slipped on and off the hook. All thimbles should be galvanized and of a size proportional to the hook and cable used.

For easy and correct installation of cables the following tools are needed: (1) brace and bit for making the holes, (2) wrench or other tool for screwing in the hooks, (3) small bolt-cutter for cutting the cable, (4) pliers for tightening down the splice.

The bits should be of different sizes according to the different caliber hooks used, remembering that the bit should always be one-sixteenth inch less than the hook. Bits must be very sharp, because green wood is harder to cut than dry pine, and holes must frequently be made at awkward angles where very little pressure on the brace can be exerted. Almost indispensable for drilling the holes is a safety belt, which allows the worker to use both hands and push more strongly against the brace. The bolt cutter is a very handy tool, for although the cable may be cut strand by strand with pliers, this method becomes very tiresome when several cables are installed at one time, whereas the bolt cutter with one snip does the job.

INFLEXIBLE BRACES

Inflexible bracing in several respects is simpler than cable bracing. In the first place, it is usually done lower down on the tree, on the trunk itself or very near the trunk, where working conditions are easier. In the second place, it requires somewhat less skill in estimating the location of the support than for cables. Thirdly, the problems of installation are less difficult, provided that proper tools are at hand.

Inflexible bracing is aimed at binding firmly together two parts where no further movement is desired. Its chief use is in weak or split crotches, ordinarily in the trunk itself, sometimes in the fork made by two major limbs. This type of bracing may be preventive or curative. It is preventive when the weakness of certain crotches is anticipated, and braces are accordingly installed. It is curative when already split trees are forced back together and bolted into position.

Many trees, the elms particularly, grow with constitutionally weak crotches, the so-called "V-crotch" as contrasted with the more sturdy "U-crotch" of the oaks and others. Such a crotch, shaped like the letter "V", is likely to split open at times of unusual stress, such as ice storms, high winds, or mechanical strain of any kind. Braces through the crotch or at a short distance above it will eliminate this danger.

When a tree is split down the center, repair work becomes urgent. At such times hours may mean the difference between saving and losing the tree. Splits occur suddenly or gradually, according to the kind of tree and the amount of stress imposed. Some splits develop over a period of years, advancing an inch or so each year, until the damaged trunk can no longer support the weight of the increasingly heavy top. Other trees split apart suddenly, without warning. In almost every case the tree can be repaired if the two halves are still together at some point along their length and if repair measures are promptly taken. After ice storms it is not uncommon to find trees split down their center to the very ground, the two halves lying prostrate in opposite directions. In all such cases the procedure is always the same: to draw together the parts with ropes or chains; to bind them in position firmly, and to install the needed braces.

Drawing together the fallen halves of a large tree is rather a difficult undertaking and requires some special equipment. Block-and-tackle, hoists, and various other lifting or pushing devices may be used. Best of all is a winch truck, which provides a slow, steady pull without danger of slippage or breakage. All parts wrapped around the tree or pushing against it should be carefully insulated with heavy padding to prevent injury to the bark.

Once the parts are drawn together, several holes are drilled through the tree at strategic points along the split portion. For making these holes extra long drills are needed. These may be bought from a tree-material supply house; every tree worker should have an assortment of varying lengths and thicknesses. The bit extension is unsafe for use in trees, for should the bit work loose from the extension, it is lost for good inside the tree.

Drilling through a large tree is a difficult procedure which should be done slowly and carefully, pausing from time to time to clean out all drill chips and frass. If part of the chips become compacted within the hole, drilling gets harder and harder, and the drill may break under the strain. It is much easier and faster to make the holes with an electric drill, but here even more care needs to be taken not to force the drill. Holes should be made about a foot or so apart throughout the split portion. They should be staggered as much as possible so as not to have successive holes in the same line of sap flow.

When the holes are made it remains only to insert the fasteners. These may be either threaded rods or bolts and nuts.

The threaded rod is perhaps stronger and somewhat neater, although more difficult to install. It is a long, nontapering rod with unexpanded ends and a screw thread along its entire length. It is screwed in with a pipe wrench until the point is just about to emerge on the opposite side and then cut off with a hacksaw flush with the tree. A size one-sixteenth inch more than the hole diameter should be used. If the rod exceeds the hole diameter by more than this fraction, the greatest difficulty will be found screwing it in, and the probability is that (in hard woods) it will twist in two. The bolt-and-nut is simpler to install. The bolt is selected somewhat smaller than the hole and pushed into it by hand or, if a tight fit, driven in with a hammer. Oval- or diamond-shaped washers should be used both at the head end and the nut end of the bolt. Moreover, oval-shaped sections of bark should be chiselled away at both ends so that head and nut may be countersunk, allowing for quick growth of new bark over the holes. Any part of the bolt that projects after the nut is tightened down should be cut off.

The advantage of bolt and nut is that when the nut is tightened down, the split parts are forced even more closely together. The disadvantage is that it is very difficult to estimate the length of bolt needed so that a very complete assortment (or else a thread-cutter) must be carried along at all times, whereas the threaded rod may be inserted into any length hole and cut off at any desired point. Whichever material is used, it should be painted with rust-resistant metal paint (which must be harmless to the tree). Also a small amount of antiseptic tree paint should be smeared around the mouth of the holes before installation is completed.

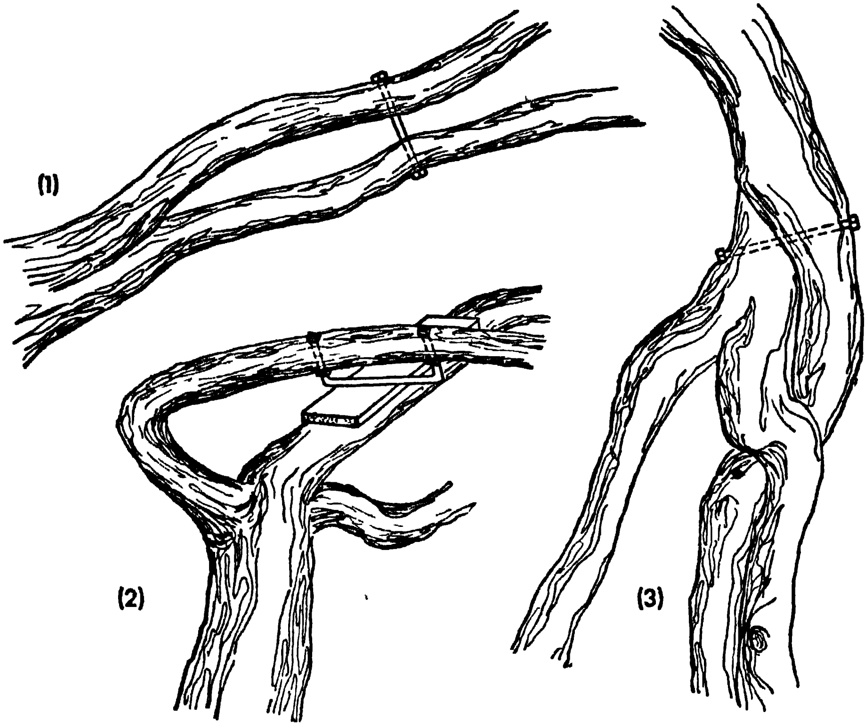
When a tree has been split down the center, one or more cables are usually installed higher up among the limbs, as a supplement to the rigid bracing below. Also heavy rods are sometimes installed through the major limbs at a point a foot or so above the split crotch. If bracing is properly done and the split parts brought back entirely together, they will soon grow together at the edges and once more become one tree.

Split limbs are treated exactly the same way as split trunks, except that the fasteners used are naturally smaller, in proportion to the size of limb involved and the amount of strain anticipated. Limbs may sometimes show long splits at some point along their length, while being perfectly sound in all other parts. When a trunk splits, it does so at a crotch, which acts like an opening wedge, but, strangely enough, a limb may split at a point where no crotch is present. Such splits may be drawn together in the usual way; however, if they have been allowed to go two or three years, they will be permanently warped out of position, and no pressure will draw them together without doing more harm than good. In such cases, the fasteners are tightened only to the point where further splitting may be prevented, and the opening is painted with antiseptic tree paint. If the split is not too wide, the edges may grow together with the passage of years. In any case the limb, properly braced, will live on unaffected, for the damage involved is purely mechanical, not physiological. If the limb is large and heavy, additional support may be given it by means of a cable passing to another limb above or opposite.

Rigid fasteners may be used through cavities to strengthen the tree at such weakened points and to make sure the edges of the cavity do not draw away from the cavity filler. They are most useful where the cavity is large and the shell of sound wood thin, for here real danger of the tree's breaking off is involved, particularly if the top is heavy and the cavity low down on the trunk. Small cavities very seldom need bracing. Cavity braces are installed transversely or, rarely, diagonally. The usual precautions of countersinking, staggering, and painting are observed.

Where two limbs are rubbing on each other, a special problem arises: If they are allowed to keep on rubbing, the bark, and even part of the wood, will be worn away, and a permanent avenue of infection opened. If one of the limbs is small or unimportant, it may be cut off and the difficulty solved. If it is considered desirable to keep both limbs, the two may be joined together at the point where they rub by means of a threaded rod or bolt-and-nut.

Usually when so joined and movement between them prevented, they form a natural graft; in any case their chafed tissues quickly heal. If it is desired to prevent their movement but at the same time keep them apart, the threaded rod or bolt may be so installed



THREE METHODS OF BRACING LIMBS. 1. Two limbs joined together with bolt and nut but kept apart by a short length of pipe. 2. Chafing of two limbs prevented by board on one and U-rod on the other. 3. Two limbs joined rigidly by bolt and nut. Threaded rod may also be used when two limbs are being joined.

that a space remains between the limbs, as indicated in the illustration. To protect it against rust the visible part of the rod may be covered with short pieces of pipe put in at the time of installation. If it is desired to allow independent movement to each limb, rubbing may be prevented by installing a buffer rod on one limb and a board on the other, as shown in the figure. The board will need to be replaced from time to time as it wears through. Instead of the board, another rod or a metal strip of some kind could be used, except that the two pieces of metal rubbing together produce a continuous and irritating noise.

Another problem occurs where a large and valuable limb rubs against a telephone pole or some other similar obstruction. Here a board bolted to the limb is probably the best solution, if the limb is too large and heavy to be pulled back by a cable. Various other such miscellaneous problems in bracing will arise from time to time, piquing the ingenuity of the tree-worker. In all cases the principles to be followed are the same, and one who understands the structure and the physiology of trees cannot fail to cope with the issue.

VERTICAL BRACING

Vertical, rigid braces are used in the rare cases when support from above cannot be supplied. Trees growing in a reclining position sometimes need to be supported from underneath, as shown in the accompanying photograph. Such braces need to be very strong, for not only the tree comes to depend on them but the people underneath as well. These braces should not be used near driveways, since if accidentally struck by a car, they may turn out to be the triggers of a trap.

Vertical braces may be made of metal pipes, concrete posts, or wooden posts. Wooden posts are, of course, the least durable. Concrete posts are valueless unless reinforced. Iron posts, painted with anti-corrosive to harmonize with surroundings, are best.

The brace should be embedded firmly in the ground, preferably in a concrete footing so that it will not sink with the passage of time. At the upper end it may be attached to the tree by one of three methods:

(1) By surmounting it with a "rocker" or "cupped hand," made to conform to the roundness of the tree. Although the tree rests very securely in the rocker, the device injures the bark and cambium at the point of contact.

(2) By providing it with a pointed rod which fits into a hole bored into the tree. The rod may go only part of the way into

the tree, like a lag screw hook, or it may traverse it entirely and be secured on the upper side by nut and washer.

(3) By installing a rod horizontally through the tree and allowing its ends to protrude several inches; then by using the same rocker structure as in (1) but with its ends curved upward more sharply so that they support the protruding ends of the rod rather than touching the tree itself.

Methods (2) and (3) do not injure the tree. Method (2), while acceptable for a limb or small tree, is unsafe for a large tree, for a hard wind may twist the tree and break the rod. Method (3) is the best of all. It provides security and at the same time allows the tree to continue growing unimpeded.

A modification of the vertical brace is the rigid horizontal or diagonal brace, used in the very special case where a leaning tree must be supported against another tree that leans in the same direction and away from it. Where the weak tree leans *away* from the anchor tree, the leaning is no problem, for cables can be used. But where the weak tree leans toward the anchor tree, the former must be made to rest on the latter rather than be suspended from it.

In such cases an iron pipe 1, 2, or 3 inches across, according to the size of the tree to be supported, makes an excellent brace. A shallow hole the size of the pipe is bored into each tree at the point of attachment. In the center of the shallow hole a large nail is driven, or a small lag screw hook is screwed in. The pipe is then fitted over the nail and into the hole. The holes need to be made at exactly the right places, determined by previously measuring with the pipe. The point of maximum support is of course sought. The nail and the hole will keep the pipe from sliding to one side, while the hole also serves as countersinking to allow callus growth to develop around the inserted pipe ends.

To prevent the pipe from falling out when the trees separate when blown by the wind, it is necessary to install a cable a foot or so above or below the pipe. The cable prevents the two objects from opening; the pipe prevents them from closing. The principle is exactly the same as that used in certain types of automotive tow-bars, where a short length of chain passes through a pipe. Because of the chain the front car pulls the rear car; because of the pipe the two are prevented from colliding.

VI

FERTILIZING

REASONS FOR FERTILIZING

TREES GROWING in a forest fertilize themselves to a great extent by annually shedding their leaves, which decay and enrich the soil. They are further fertilized by other decomposing plant matter and by decomposing animal matter. In addition, the soil is usually quite porous, allowing free passage of air and water. Rains are frequent, and the water is prevented from running off by the loose mat of debris and the thick, porous layers of humus.

In city areas most of these conditions are reversed. Leaves are swept up and burned or hauled away. No plant and animal debris is allowed to accumulate under trees. The ground around them is either covered with cement or asphalt or is tightly packed by walking on it or is covered with heavy sod, making it difficult or impossible for water and air to reach the roots. The water supply, both underground and above ground, is almost always inadequate.

Because of these highly unfavorable conditions, trees growing in city areas need to be artificially fed and watered. Some need it more than others, but nearly all of them need assistance unless growing along a stream or in some abandoned back lot.

Superficial feeding and watering of trees has not proved satisfactory. Food scattered over the top of the ground and water sprinkled on it seldom reach the hungry tree roots below. Most of both food and water are absorbed by the turf growth that usually surrounds city trees.

Hence, a method of feeding that breaks through surface coverings and puts the food where the roots are found is the only method that can benefit the tree.

LOCATION OF ROOTS

It is often said that the roots of a tree extend as far outward as its branches. Many people find this hard to believe, having in the back of their minds the relatively small root-ball moved with shrubs and transplanted trees. In fact, however, the roots of an established tree not only extend as far as the branches but usually much farther —in some cases two, three, or four times farther.

Oddly enough, those who find difficulty in believing that the roots extend outward so far often accept without question the popular belief that the roots go down as far as the tree goes up. This, apart from very exceptional cases, is certainly not true. Ordinarily the roots go down only a third, a fourth, or a fifth of the tree's height, and then only some of them go this deep, mainly the huge anchor roots and, in some trees, the taproot, which often makes a spectacular descent in search of underground water. However, the feeder roots are always close to the surface, for the most abundant and richest food is to be found in the layer of topsoil. The feeder roots of nearly all trees occur within two feet of the surface.

PLACE TO FERTILIZE

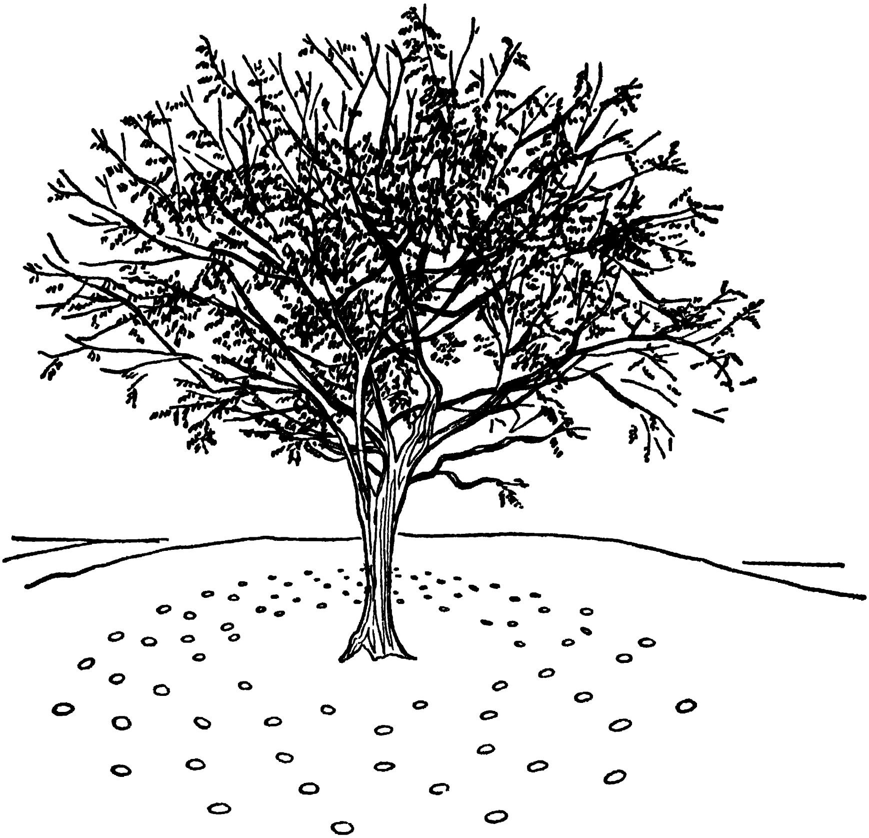
By considering root location, it becomes obvious that fertilizer should *not* be applied: (1) close around the trunk of a tree; (2) too shallowly (sprinkled on top); (3) too deeply (more than two feet down). The commonest error in feeding is to apply the fertilizer immediately around the trunk, doing little if any good and sometimes doing harm, particularly in the case of young, tender-barked trees which are easily burned.

The area in which the fertilizer is most effectively placed is *the outer two-thirds of the branch spread and one third beyond.* Directions frequently given on commercial fertilizers recommend application under the branch drip. Although this is approximately right, the area indicated above is better because it is broader.

MANNER OF FERTILIZING

Throughout the indicated area small holes are made about 2 feet apart and about 1½ or 2 feet deep. How many holes should be made?

Enough to accommodate the required quantity of fertilizer, which for large trees may be several hundred pounds, for medium-sized trees 30, 40, 50, 60 pounds, for small trees 5 to 10 pounds.



Method of feeding tree by making holes 1½ feet deep beneath the outer two-thirds of the branch spread.

The holes may be made at random throughout the area, or may be made in a pattern of concentric rings. The essential thing is that a more or less even coverage be obtained, so that one side of the tree is not starved, while the other side gets a double dose. (In cases where a tree is near a building, only half the root system can be fed, of course.)

Many devices have been developed for making the holes. The simplest and least expensive is a straight, pointed iron bar about six feet long and 1½ inches through, which is forced into the ground manually by repeated jabbing. In reasonably soft ground a strong man can make 100 holes or so in about two hours. Each time the bar is jabbed in, it should be wiggled around to make it easier to pull out and to make the mouth of the hole somewhat larger for the easier pouring in of the fertilizer.

In very hard or rocky soil it is often necessary to use a shorter bar (2½ feet long) and to drive it in by sledge hammers.

Special earth augers driven by electricity or compressed air are often used by large companies where the soil permits. These have the advantage of being faster and easier than the bars and of making a somewhat larger hole with sides less compacted.

Another device utilizes the erosive force of water ejected at high pressure. It consists of a pipe with a small hole in the end, which is gradually worked into the ground, thus digging the hole and softening and watering the surrounding soil at the same time. Some large companies achieve the same effect by using jets of compressed air.

Extremely compacted soils are sometimes loosened by dynamiting. Instead of harming a tree, as might be supposed, dynamiting is beneficial by adding nitrogen to the soil, as well as by loosening it.

Amateurs sometimes try to make holes with a posthole digger. This tool makes too large a hole and damages too many roots in the process. The pointed bar damages roots only very occasionally. Its greatest damage is to the drainage pipes, copper pipes of sprinkler systems, etc. One of the reasons for not making holes close to the trunk is to avoid injury to the large, muscular roots that are usually more clustered and nearer the surface at that point.

Once the holes are made, they are filled about three-fourths of the way with the fertilizer mixture. If the fertilizer used is a solid or a powder, water must be added to it, for it cannot be absorbed by the roots until it enters into solution. If the fertilizer is applied in liquid form, no watering is necessary.

If applied as a powder, it can be conveniently mixed with a hoe in a wheelbarrow and then poured into the holes with a gallon or half gallon can bent to form a pouring spout. It can then be watered with a garden hose directed into each hole. It is desirable to keep these holes open as long as possible.

KIND OF FERTILIZER

There are as many different opinions about the best kind of fertilizer as there are about the best kind of automobile. Many people will use only horse manure, others sheep manure, some prefer leafmold, bone meal, etc. Actually, all of these are good fertilizers, and none need be exclusive of the others.

The essential ingredients needed for plant growth are nitrogen, phosphorus, potassium, iron, calcium, magnesium, sulfur, manganese, boron, copper, zinc, and molybdenum. Most commercial fertilizers contain principally the first three elements, expressed as a proportion, such as 5–10–5, 6–8–4, etc., indicating the relative amounts of each. Often other elements, such as boron and manganese, are present in small quantities. In recent years some companies have systematically included the lesser-known elements, hence increasing the value of their product.

Certain abnormalities of trees may be remedied by applying the right kind of fertilizer. Each particular element has a particular influence on plant growth. Where iron deficiency is indicated, it would be idle to supply pure nitrogen, although nitrogen and iron *both* would be of value. An expert is needed to diagnose abnormalities caused by deficiencies of the minor elements. But within the reach of everyone is the application of a well-balanced fertilizer as needed or at regular intervals. Fertilizers frequently help, very rarely harm, unless applied in overdoses or directly against stem or trunk.

Fertilizers are useful not only in maintaining a tree in normal health but also in providing it with a stimulus to hasten healing over pruning wounds or over recently repaired cavities. Many large companies do not undertake extensive pruning or cavity repair unless authorized to feed the tree at the same time.

Nitrogen is the element most responsible for the maintenance of green color in leaves; also for normal twig growth. It is more frequently lacking in shade trees than in orchards, since there the systematic plowing under of cover crops insures its replenishment.

In the forest it is replenished naturally in the form of humus (decaying animal and vegetable matter). Since it is abundantly present in barnyard manure, slaughterhouse refuse, and other organic products, these are among the best of fertilizers. It is also obtained from sodium nitrate, calcium nitrate, and ammonium sulfate. Leguminous trees, such as the locusts, the mesquite, the redbud, etc., actually add nitrogen to the soil by means of colonies of nitrogen-fixing bacteria that grow in nodules on their roots.

Potassium or potash assists in the manufacture of sugar and starches. It also helps tissues mature properly and heightens the color of flowers. Plants deficient in potash may become either too succulent or too brittle.

Phosphorus assists in the maturation of tissues and stimulates root growth. It is particularly important in the production of flowers, fruits, and seeds. Since it normally penetrates the ground very slowly (as contrasted with the rapid leaching action of nitrates), it should be applied by the punch-bar method.

Magnesium and *iron* are essential to the formation and maintenance of chlorophyll. Where lacking, leaves are yellowish and unhealthy.

Calcium serves a number of purposes, not the least of which is to "sweeten" the soil and favor the activities of beneficial microorganisms.

Formerly the commercial fertilizers sold for dressing lawns were not quite adequate for shade trees. Many of today's lawn fertilizers, however, are higher in nitrogen content, and can be used as effectively on trees as on the turf at their feet.

Although it is possible for one to mix his own fertilizer from raw elements according to a strictly scientific formula, it is seldom practical to do so. A good fertilizer can be made by mixing a commercial fertilizer in roughly equal parts with sheep manure (or horse manure, cow manure, or tankage), and adding nitrate of soda, bone meal, and copperas (iron sulfate), where needed. This type of mixture supplies all the needed ingredients in about the right proportions and, further, in such a manner that their action is continuous over a period of time, some taking effect immediately, others acting more slowly.

SPECIAL CASES

There are, of course, special cases that demand a modification of the fertilizer composition. In some soils aluminum sulfate needs to be mixed with iron sulfate in order to make the iron available. In others the soil needs to be changed from acid to alkaline, or from alkaline to acid. For example, most shade trees grow in slightly acid soil (pH value of 5.5 to 7.0).

Ground limestone will increase the alkalinity of soils, while aluminum sulfate and sulfur will increase their acidity. The pH value of any soil can easily be determined by means of a soil-testing kit costing less than ten dollars.

Not all trees respond equally well to fertilizing. Oaks, elms, pecans, walnut, and basswood usually show a high degree of response quickly. Some trees react very slowly, while others may actually be harmed, due to a complication of other factors. The pear tree, for example, may become badly attacked by fire blight when excessively stimulated by nitrogenous fertilizer; hence it is better for this tree to receive food low in nitrogen content, or none at all.

AMOUNT OF FERTILIZER

Trees 6 inches or under in diameter (DBH)[1] should be fed at the rate of 2–3 pounds for every diameter inch. That is, a 6-inch tree should get 17–18 pounds, a 4-inch tree 8–12 pounds, etc. Larger trees are usually given 5 pounds per diameter inch (DBH) Thus a 3-foot tree needs about 180 pounds of fertilizer. The arithmetic involved is very simple. The required quantity is determined and enough holes are made to accommodate it. That is all.

TIME TO FERTILIZE

In general, the best time to fertilize is in early spring because at that time new growth is most active and adequate nutrients must be available to accommodate the demand. Fertilization in midsummer is less effective, and in late summer it should be avoided, as any new growth stimulated at this time stands a good chance of being injured by early frost. Fertilization in winter produces no apparent effect, although the materials are not lost, since they remain in the soil and are picked up by the roots early in the following spring. Indeed, some arborists believe late fall or winter the best time. A tree that is weak from lack of proper nutrients, however, should be fed, if practical, whenever its sickness is discovered, regardless of the season.

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[1] Diameter at breast height.

FREQUENCY OF APPLICATION

How often should trees be fed? Once a year, twice a year, once every two years? The answer depends, of course, on the kind of tree and the circumstances.

Generally a tree in good color and high vigor need never be fertilized. Why tamper with something perfect? On the other hand, a below par tree or one diseased, attacked by insects, or damaged mechanically, should be fed abundantly once every year or once every two years until it recovers. After that, it should be fed as needed, with the intention of "tapering off," if possible.

Some trees may need only one feeding in a lifetime to enable them to overcome some temporary ailment. Others may need periodic feeding once a year, or once every two or three years all their lives. Although feeding is an artificial measure, it is only so because artificial conditions have prevented natural feeding; hence it cannot be considered "habit-forming," as some people seem to believe.

SOIL IMPROVEMENT

In spite of its extreme usefulness, fertilizing is only a part of a soil-improvement program. If the soil around a valuable tree is exhausted or vitiated, it may need to be dug out and replaced entirely. This may be done gradually over a period of years and, although very expensive, is an almost certain method of rejuvenation.

Soils that are too thin or sandy may be improved by the addition of heavy, rich soil. Conversely, soils too wet and clayey should be spaded up and mixed with sandy loam or fine gravel. Most soils can be improved by the incorporation of humus.

By means of the leaves a tree takes in carbon and oxygen from the air, which is nearly constant; it takes in hydrogen from the water imbibed by the roots. All the rest of the elements necessary to plant growth come from the soil. Their presence or absence and their degree of availability are largely responsible for the differences of vigor among trees having similar heredity. Hence we may coin an aphorism: *No tree is better than the soil in which it grows.*

OTHER METHODS OF FEEDING

Trees may be fed by methods other than through the soil, although soil-feeding is probably the best method and the one giving the longest-lasting results. They may be fed by (1) spraying the leaves; (2) spraying or painting thin-barked trunk and lower branches; (3) injections into the trunk.

(1) Nutrients may be sprayed onto the leaves in liquid form and absorbed immediately. This method is particularly useful in cases of chlorosis. The method gives immediate results but is not so long-lasting as soil fertilization.

(2) Liquid nutrients may be sprayed not only on leaves but onto trunk and lower branches as well when the bark is thin enough to permit their absorption. Recent experiments, particularly on fruit trees, indicate that many of the necessary fertilizer elements can be applied to a tree in this manner; also by painting or swabbing the nutrient solution onto these parts. Radioactivation of the nutrients, followed by their tracing with Geiger counters, establishes the fact of their absorption and internal distribution beyond any doubt.

(3) Direct injection into the trunk is now successfully practiced as a remedy for various abnormal conditions. The substance injected may be a liquid or a solid. If a liquid, it needs to be in special containers, attached to or suspended from the tree, and injected slowly over a period of hours or even days. Such methods are not practical under city conditions, for small boys or curious passersby are almost certain to meddle with the apparatus. This method has been used, among other things, to inject certain organic dyes into maple trees for the treatment of bleeding canker.

Injection of a solid is by comparison quite simple. The material to be used is prepared as a capsule with an easily soluble coat. With an ordinary brace and bit, a hole half an inch wide or so is drilled into good sound sapwood to a depth of 2 or 3 inches—slanted slightly downwards so that when the material dissolves it will not run out. The capsule is put in and the hole sealed up with putty, asphalt, or cement. The capsule coat dissolves, the substance inside gradually does the same, enters into the sap stream, and is carried to all parts of the tree.

While many materials may be applied in this manner, the substance most commonly used, and consequently the one about which the most data have been assembled, is iron salts, used for the treatment of chlorosis. The iron is usually applied as ferric phosphate, at the rate of 5 grams for every inch of trunk diameter. For a large tree several holes distributed equidistantly around the trunk should be bored.

Complete fertilizers may also be applied in this way. Trees have been given experimental injections of urea, potassium phosphate, and other substances with gratifying results.

The disadvantage of trunk injection is the danger of introducing wood-rotting fungi or wood borers or other insects, particularly where the holes are imperfectly plugged up. The method cannot be considered as valuable as soil fertilization, although it may serve as a substitute where buildings, streets, sidewalks, or other obstructions limit the area for root fertilization.

VII

SPRAYING

SPRAYING IS ONE of the most important parts of tree care. At the same time it is perhaps the part that demands the most knowledge and requires the most caution.

Spraying, like land-clearing, lake-draining, river-changing, etc., interferes with the balance of nature, which, although it may not seem so, is always in a state of very delicate equilibrium. Although such interference is often desirable, its consequences are not always foreseeable. An activity that is apparently completely innocent may invite sudden calamity. The remedy may prove worse than the disease, may in fact aggravate the disease.

Among the factors to be considered before a spray is applied are these:

temperature
humidity
wind
compatibility of spray ingredients
correct dilution of spray
kind and stage of insect or fungus to be controlled
kind and condition of tree or shrub being sprayed
date of last spraying and possibility of harmful residue.

These factors, and others, sufficiently complicate spraying. It is impossible to lay down a general rule to fit all sprays and all trees. Each type of spray has its particular temperature and humidity requirements. Each species of plant has its particular susceptibility.

Unquestionably, the new spray materials are very effective, particularly the new organic insecticides. Moreover, better materials will continue to be developed. Yet it seems improbable that there will ever be a foolproof panacea: first, because of the varying susceptibility of plants themselves, and second, because of the marvelous adaptability of insects, which can build up resistance to even the deadliest of poisons. If eternal vigilance is the price of liberty, eternal study and observation are the price of insect and disease control.

TIMELINESS

As important as choosing the correct spray material is the timeliness of its application. Most fungus and bacterial diseases, for example, must be prevented, not cured. This means that the spray material must be applied *before* the spores have an opportunity to penetrate the leaves. Usually, as for anthracnose prevention, application is made just as the new leaves reach full stage of growth. Subsequent rains will wash the material off, and for new growth supplementary sprays are recommended.

Spraying for insect control is just as difficult. Sometimes there is an interval of only two or three days when the harmful insect is active. If the spraying is not done at that time, it is wasted. Spraying before is like firing ahead of the duck; spraying later is like firing behind him.[1]

Bagworms are a good example. They must be sprayed when actually eating the leaves. Spray applied before they appear deteriorates and loses its effect; also unprotected new growth appears. Spray applied when they have finished feeding and are retiring into their cocoons affects them no more than rain affects us inside our house.

Control of the plum curculio is another example. Once the egg is inside the developing fruit, all subsequent spraying is wasted.

Fortunately, not all insects present so difficult a problem. If they did, one might well give up and let things take their own course. Many insects, such as plant lice and scale, may be sprayed any time they become abundant. Plant lice and some forms of scale are almost always in the garden and on the trees. They are never eradicated, only controlled. A certain number of insect pests is normal. It is only when their numbers become epidemic that the gardener needs to become alarmed.

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[1] Recently, sprays with lasting residual effects have been developed. With these, timing is not as important. However, they tend to be more concentrated, and this may make them injurious to plants.

It is impossible in a book of this kind to lay down spraying schedules, for these vary from region to region. In our southern states most trees flower and set fruit in March and April, in our northern states some of the same kinds may not flower until June. Even within the limits of a single state the variations are considerable. Only experience, observation, and consultation with neighbors and with local county agents can determine when you should spray and for what.

REPETITION

This brings up another point: spraying needs to be repeated. One spraying seldom accomplishes 100 per cent results. In the case of insects, the first spraying may kill 75%, 80%, even 90%. But those left rapidly build up their numbers again, so that in a short time the spraying must be repeated. Even in the rare case of 100% destruction, other insects can fly in from all points of the compass and reinfest the tree within a few days. (See also page 120.)

In the case of fungus and bacterial diseases that enter through the foliage, spraying needs to be repeated whenever the protective film over the new leaves weathers off and whenever new, unprotected growth appears.

The homeowner with one or two shade or fruit trees may well wonder whether it is worth the effort and the cost to keep his trees insect and disease free. Often it is not, to be quite truthful about it. "I think I like a speckled axe better," said Benjamin Franklin, after turning the grindstone a few minutes. You as a homeowner may decide you don't mind a few insects on your trees, after spending large sums trying to eliminate them.

Many homeowners are unnecessarily alarmed at the accidental discovery of an insect-eaten or diseased leaf, when in reality every year they have had the same thing without noticing it. Frequently they have their trees sprayed at a time when the disease is already clearing up or the insects naturally disappearing. In such cases the one who does the spraying takes full credit for the cure and thus gains the complete confidence of the homeowner. *Caveat emptor!*

The really serious cases of epidemic infestations or fatal diseases are in a different category, of course. These demand the best efforts of the most experienced and most conscientious arborists. Where the life or death of a valuable tree is at stake, one might well afford to spray up to ten times if need be.

(On the other hand, some spray materials, such as DDT in certain concentrations, have been observed to have an adverse effect on trees when used too frequently.)

TYPES OF SPRAYERS

Sprayers work on a very simple principle: the principle of hydraulic pressure: the same principle that makes a hydraulic jack raise a car, brake shoes close against a brake drum, and blood spurt from a wound.

In all sprayers air pressure is built up in a tank containing liquid. By mechanical means the air is compressed; the air pushes against the liquid, and the liquid is forced out through a tiny orifice, which may be opened or closed at will. The greater the pressure the more forceful the flow from the orifice. The orifice (nozzle) is so made that it may adjust from a solid stream to a fine mist. All the mechanical sprayers also have an agitator to keep the solution thoroughly mixed during the spray operation. In hand-operated sprayers the solution is agitated manually.

Small, three-gallon tanks are made to be carried about on the back or slung over the shoulder. They are pumped and agitated by hand. Although designed principally for flowering plants and shrubs, they will do for trees up to 10 or 12 feet.

Wheelbarrow sprayers have a larger tank capacity and build up somewhat greater pressure. For trees, however, their limits are about the same.

Only power sprayers are adequate for large trees. In the first place, their tank capacity is larger. In the second place, they force the liquid out at greater pressure, thus breaking it up into finer mist which insures better and more economical coverage. In the third place their mechanical agitator provides for a thoroughly mixed solution of a constant consistency.

Power sprayers are available in many different models, from small, hand-pushed, wheelbarrow-like affairs designed for gardens, greenhouses, large estates, small orchards, golf courses, etc., to the very large units made to be mounted permanently on a special truck. Some of the largest models have hoses and nozzles almost as formidable as those of the fire department. They can throw a solid stream 80 feet into the air that breaks up into a fine mist and floats over all parts of the tree.

All power sprayers should be equipped with hoses 100 or 200 feet long, which when not in use are rolled up and hung on special hooks. By means of a long hose all the trees around a residence can easily be reached although the spray truck is parked in the street.

The newest development in sprayers is the blower or mist blower. In these machines the spray materials are let into a powerful stream of air through nozzles that break up the material into the size of fog particles. Agitation of the topmost leaves in the tree by the air stream is a measure of the effectiveness of the operation. The finely dispersed spray particles filter down on the foliage as mist does. By the use of spray concentrates, an economy in time and labor is realized. The blower's limitations in maneuverability prevent its supplanting the hydraulic rig entirely.

TECHNIQUE OF SPRAYING

The basic idea in spraying is to wet all parts of the tree thoroughly. Obviously, it would do no good to spray only one branch of an infected tree. Similarly it does little good to wet only the upper surface of leaves or only the lower surface: both surfaces need to be wetted. In addition to the leaves, the twigs, branches, limbs, and the trunk *itself should be sprayed; many times even the ground* around the tree.

While thoroughness is absolutely essential to successful spraying, this does not mean that the plant needs to be saturated until the spray runs off. Saturation merely wastes spray material without in-

[illegible] effectiveness. The ideal is to wet all parts uniformly and thoroughly and then to stop.

With a hand sprayer, thorough coverage is obtained by the operator's working around and around the plant, moving the nozzle from side to side and up and down in such a manner that both upper and lower leaf surfaces will be covered. Trees up to 12 and 15 feet high may be sprayed by the help of a stepladder.

Regardless of the thoroughness of coverage, the spray material sometimes runs off as fast as put on, particularly on smooth, waxy foliage. Hence materials called "spreaders" or "stickers" are added to the solution to break up surface tension and make the material cling to the leaves.

Some of the most-used spreaders and stickers are soap flakes (or liquid soap), fish oil, calcium caseinate, resin, glue, common flour, and billboard paste. Glue, at the rate of 1 ounce to 100 gallons, is an excellent sticker. Used a little stronger, it actually sticks down some of the smaller insects, such as red spider, and kills them by immobilizing them, as fly-paper kills flies. Common flour, used at the rate of 2 to 4 pounds per 100 gallons of water*(2 to 3 tablespoons per gallon), is perhaps the safest of the spreaders, producing no chemical reaction with any of the spray ingredients. Oil emulsions, while good spreaders, may in the growing season cause burning and destruction of bloom on ornamental plants. Most proprietary spray materials come already mixed with spreaders and stickers.

While hand-spraying is comparatively simple, power-spraying involves a few complications. Power-spraying is best done on still days or days with a very gentle breeze. If the operator does not want the spray to fall on him, he should take advantage of whatever breeze there is by so placing himself that the spray material is carried away from him and toward the tree. Very windy days are always to be avoided since the spray material may be carried three or four blocks from the point of operation.

Use of a power sprayer in residential areas always involves potential damage to others. Like loud noises, encroaching spray material may be considered a disturbance of the peace and a violation of the rights of others. Neighbors, unmindful of the [illegible] of tree care, may be annoyed by spray material falling on [illegible]. They may [illegible] truthfully or untruthfully, [illegible]

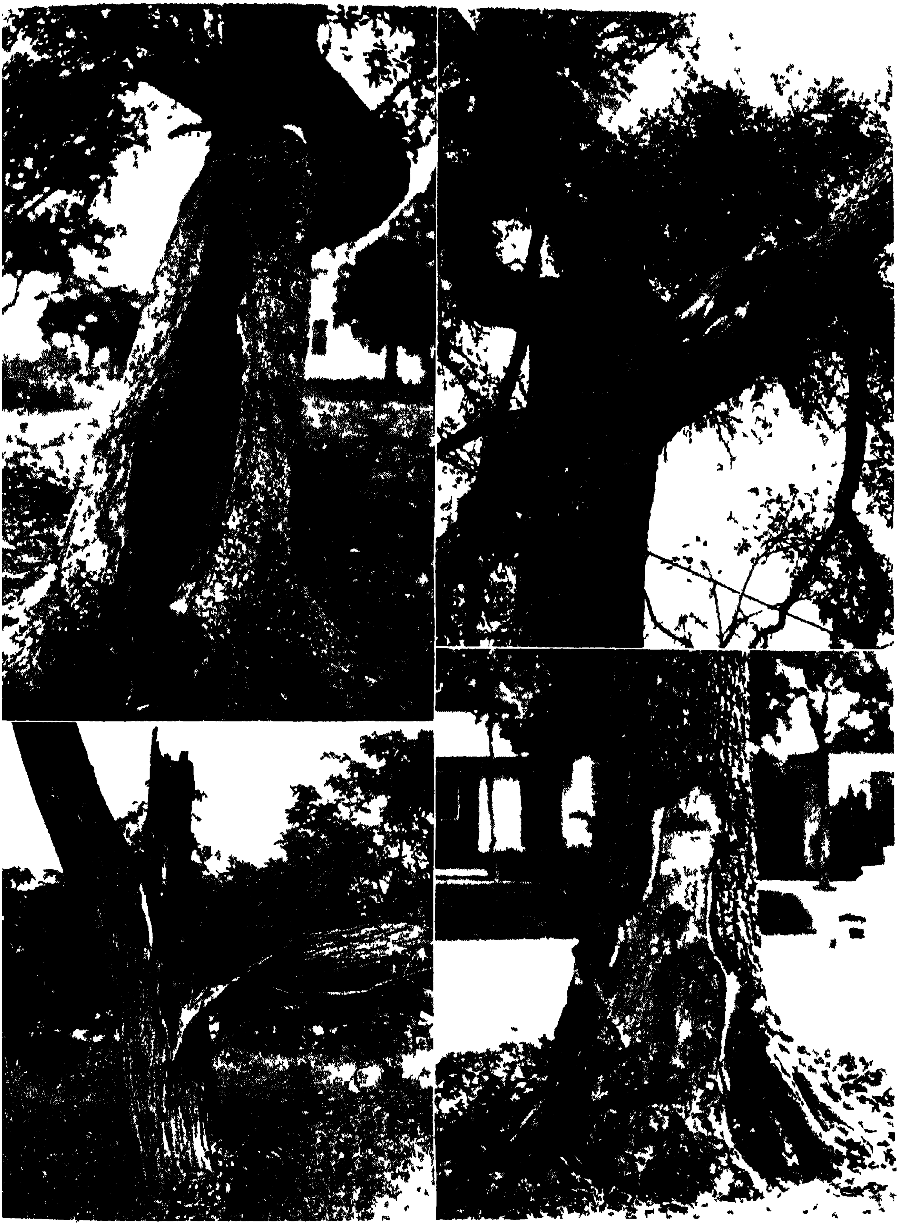

Plate 11 PREVENTABLE DAMAGE *Upper left* A tree weakened by cavities may die unless properly repaired *Upper right* Cabling and cavity repair would have saved the lost limb, and may yet save the large one if done in time *Lower left* The neglected stub initiated decay, the resulting cavity weakened the tree and it blew apart *Lower right* This tree needs proper shaping of the wound and repeated painting with tree dressing

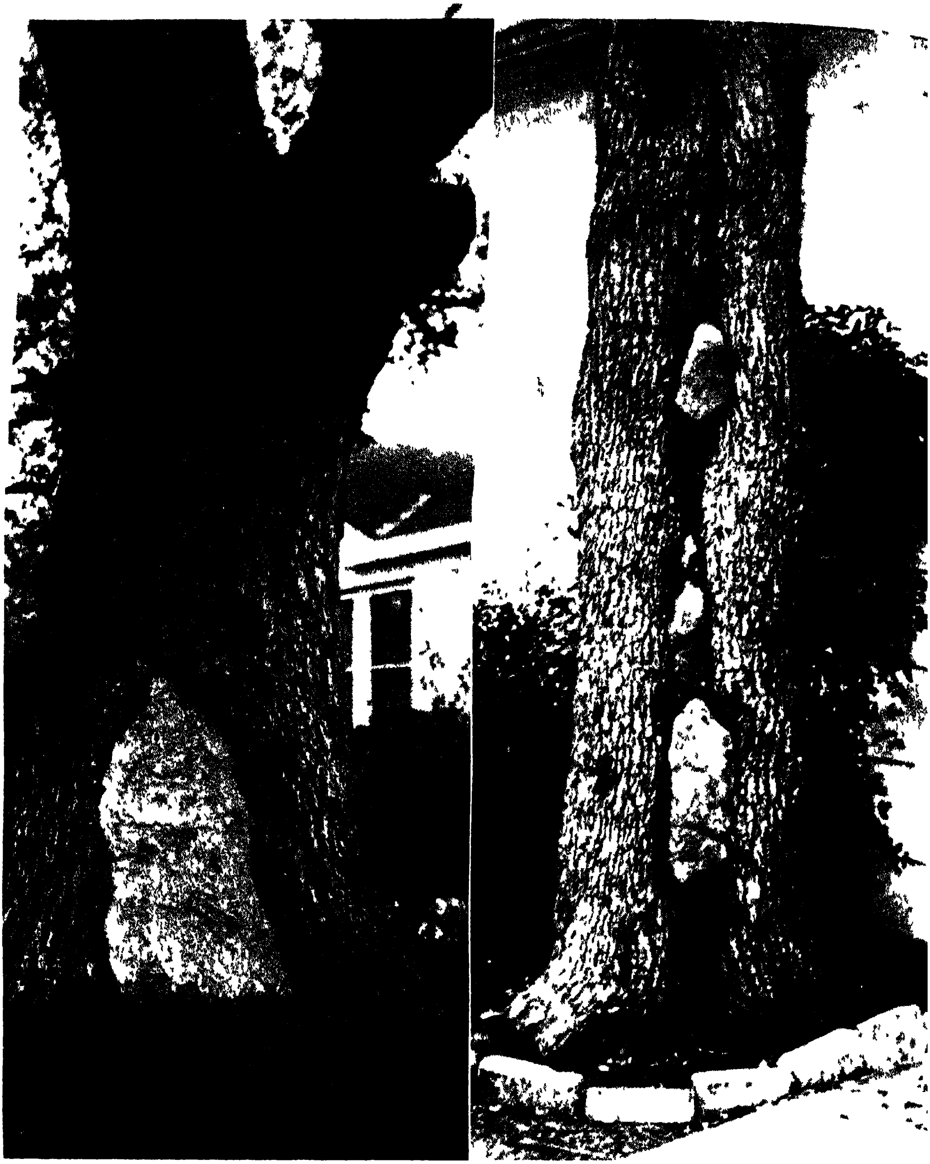

Plate 12. HOW NOT TO FILL A CAVITY. *Left.* Four things are wrong here: (1) The cavity is not cleaned out properly behind the concrete. (2) The filling does not follow the cavity into the ground. (3) There are no section dividers. (4) The concrete has been plastered over the edge, covering healthy bark and impeding normal healing processes. *Right:* The concrete has broken into pieces because the new callus, which cannot grow over it, is striving to close together behind it. It is better to leave a tree to its own resources than to tamper with it ignorantly.

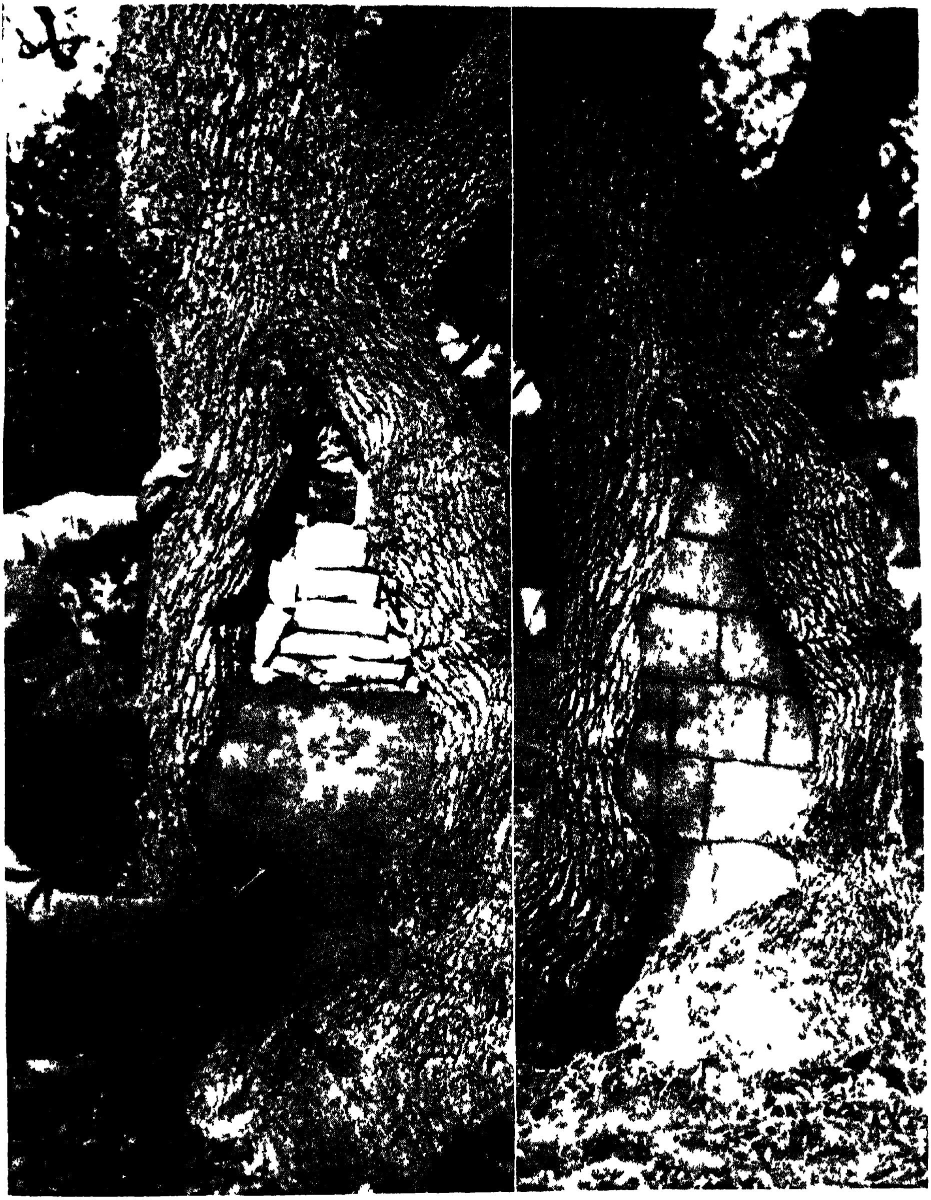

Plate 13 THE RIGHT WAY TO FILL A CAVITY *Left* Rocks used as backing save on concrete (an unorthodox but effective method) The concrete is put in almost dry a little at a time and must be tamped thoroughly especially around the edges The spoon shaped tool is a cavity slick for smoothing and polishing the face of the filling *Right* The same cavity finished Section dividers are inserted to prevent cracking when temperatures change Recessing the filling allows the callus to grow over it and seal the wound at the edges

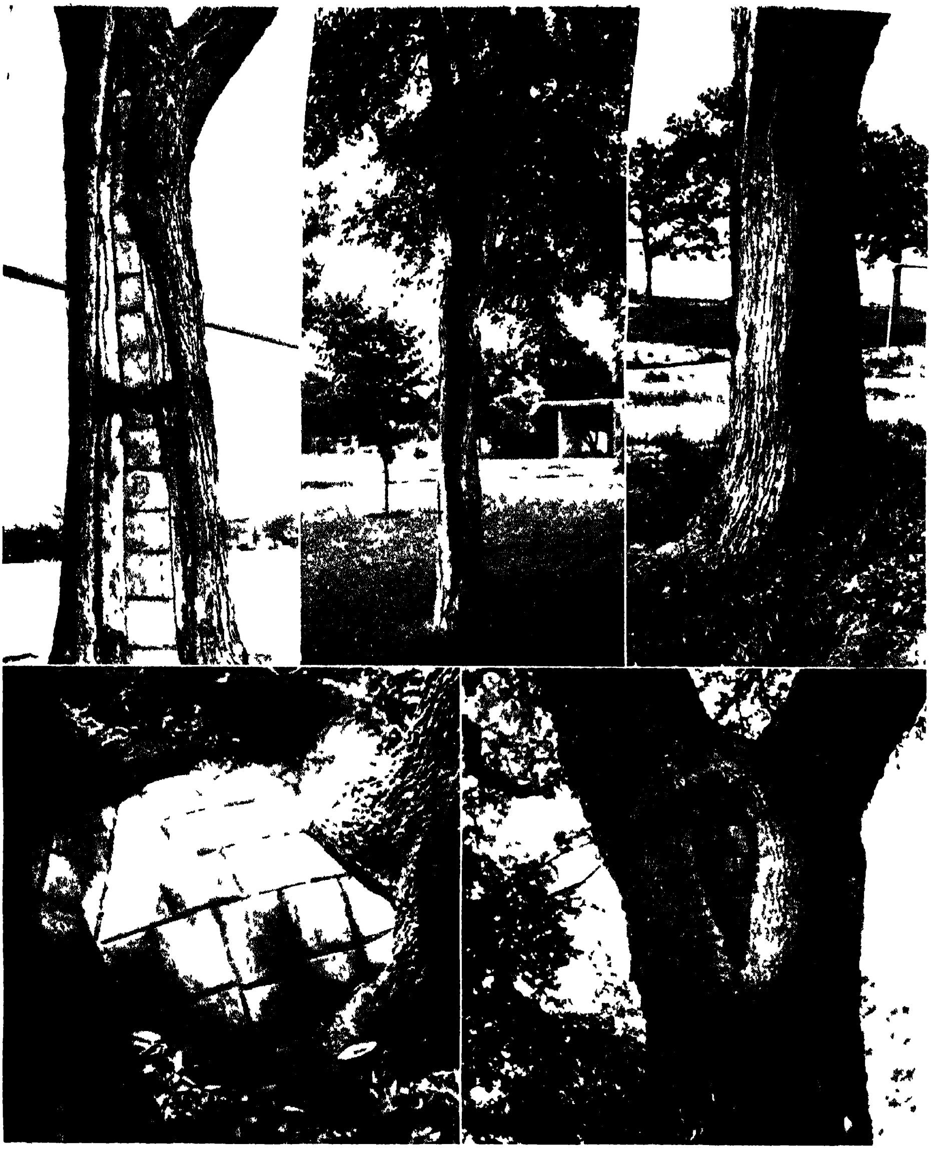

Plate 14 WOUNDS AND THEIR TREATMENT. *Above, left:* Careless excavating has caused this cavity to die back from the edge of the concrete. Callus has farther to grow, while the exposed sapwood is already decaying. *Center:* Lightning caused a bark wound, but left the exposed wood sound. Painting with a tree wound dressing is sufficient here, since new growth is already closing the scar. *Right:* A bark wound, traced and pointed to promote rapid healing, needs only a tree wound dressing, periodically applied. *Below:* Properly filled cavities, carried into the ground and up into the trunk as far as decay progressed. Note drainpipe at bottom of cavity, *right.*

tial, that it makes them ill, or their children or pets ill, that it contaminates the water of their swimming pool, that it poisons their food, that it ruins their party, that it damages their shrubbery, or that it stains their house or automobile.

To such complaints there is of course no answer, for legally they may be sustained. The proper thing to do before spraying is to get permission from the neighbors and to ask them to close their windows and move their cars if possible. Tender plants likely to be affected can be covered with canvas. If the tree to be sprayed is in a park or near a busy thoroughfare, sometimes a small area around it may be roped off to exclude pedestrians. One can hardly be too careful. The legal implications of injuring a third party with spray material are not to be taken lightly.

The operators themselves should wear masks. Repeated inhalation of toxic materials can become serious. Even contact with the skin should be avoided. The hands should be protected with rubber gloves, and the hands, arms, and face carefully washed with soap and water after each spraying or mixing.

Spray that accumulates on a street or a sidewalk should be immediately washed off with a stream of pure water to prevent possible after-effects on children or pets playing in it.

MAIN USES

The main uses of spraying are these:

(1) For the control of injurious insects.
(2) For the control of bacteria, fungi, and viruses.
(3) For the control of extraneous growths, such as lichens, Spanish moss, and ball moss.
(4) For the inhibition or stimulation of growth of the plant or development of some of its parts.

Point (1) is discussed in the chapter *Insect Control*.
Point (2) is discussed in the chapter *Disease Control*.

Spraying for disease control may be divided into [illegible] the application of protectants or eradicants [illegible] when they are outside the host, and (b) the [illegible] *which are absorbed by the leaves and translocated internally to the locus of infection.*

Points (3) and (4) are discussed below.

(3) Some trees, particularly in our southern states, become so heavily covered with lichen, Spanish moss, or ball moss as to need spraying.

A lichen is not a parasite; it merely clings to the tree, as it clings to a rock, deriving its nourishment independently through the photosynthetic power of the constituent alga. It can, however, do harm in the rare cases where it occurs so abundantly as to interfere with the lenticels (breathing pores) of the tree. Many oaks in a state of declining vigor are often heavily scaled with lichen. It can be killed by spraying with a lye solution (3 parts of lye to 100 parts of water) when the tree has shed its leaves. In the rare cases where it seems justifiable, the limbs can be cleaned by scraping with a wire brush.

The Spanish moss and the ball moss (both discussed in chapter on *Miscellaneous Troubles*) are also epiphytes, not parasites, but they too may do harm where they occur overabundantly. The same lye solution spray or sometimes an arsenate of lead spray is effective against them, burning them to death, although the withered remains hang on the tree for a year or so afterwards.

(4) Hormones are chemical substances that accelerate or retard certain aspects of plant growth. One of the most commonly known hormones, practical and spectacular in its results, is the weed-killer, 2,4–D. This material, sprayed directly onto the plant, kills by causing such an overstimulation of growth that food cannot be absorbed rapidly enough to accommodate the new demands. Other hormones of extremely practical importance and interest are those that assist in the formation of new roots on a cutting or a transplant,[2] those that accelerate fruit production without the necessity of pollination, those that restrict the formation of fruit, and those that enable a tree to retain its fruit until maturation.

[2] The initiation of root activity has been induced in some cases by soaking root systems of plants for periods up to 48 hours in dilute solutions of auxin ranging from 2½ to 150 parts per million. The auxin most used for studies was indolebutyric acid. A considerable amount of root growth was observed in certain shrubs such as viburnum, cotoneaster, honeysuckle, and some hardwood trees such as American elm, hard maple, black oak, pin oak, eastern red oak and black walnut. Conifers exhibited little response. See L. J. Audus, *Plant Growth Substances.*

ADVICE TO HOMEOWNERS

Do not try to spray your own trees. Do not have them sprayed unless you are given convincing reasons why it should be done. Do not deal with itinerant door-knockers. Deal only with a reputable arborist who is ready and able to take responsibility for his work. If in doubt, consult with your county agent or your state experiment station; they will be glad to help you.

VIII

INSECTS

THE INSECTS, like the poor, we shall always have with us. There were insects on the earth millions of years before man appeared, and the last living creature on our planet, as it slowly freezes in the heatless rays of a dying sun, will very probably be an insect.

Insects are fitted in many ways to win in the relentless war of survival. Consider their small size (which instead of being a handicap is an advantage more often than not), their prodigious numbers, their reproductive facility, their marvelous powers of adaptation. Consider their lack of intelligence, memory, and emotion, by virtue of which they waste no time in reflection, regret, hopes, or fear, but pursue directly and undistractedly their objectives—the satisfaction of their hunger and perpetuation of their kind. They can eat anything, including soap and match-heads. In cases of need they eat their fellows, or even parts of their own body. They can adapt to anything, even to DDT and hydrocyanic gas. When they fly, they darken the sky. When they go on the march, nothing can obstruct their progress. They have honeycombed the earth, dominated the sky, invaded the waters, infiltrated all plant and animal organisms. They are omnivorous, ubiquitous, uncountable, indestructible.

In many ways insects are quite different from vertebrate creatures. Instead of having lungs, they breathe through a series of small openings distributed over their body. (The goal of many insecticides is to clog up these breathing pores.) Instead of having an internal skeleton endowed with the power of continuous growth, they have no skeleton at all, or at best only an outer horny shell which must be shed from time to time as they outgrow it. (If a boy were put into a suit of armor at the age of six, he would have to change it for a larger one every year or so until he became an adult. The discarded armors of the cicada are familiar discoveries on tree trunks in the summertime.)

The peculiar growth habits of the insects cause us to see them many times without recognizing them. Although "the child is father to the man," and looks enough like him to prove it, who can imagine the maggot as father to the fly? Or the spiny grub father to the beautiful luna moth? Or the insatiable wood borers to the totally dissimilar adult beetle?

When insects have what is called a complete metamorphosis, they exist in four forms: egg, larva, pupa, adult, each form greatly different from the other and developing in the order named. When they have an incomplete metamorphosis, they exist in three forms only: egg, nymph, and adult, the pupa being omitted.

The larva is the eating stage, when the insect does most of its damage to plants. It is variously called grub, caterpillar, and maggot. To most of us it is a "worm"—a many-footed, restless, imprudent, and very hungry crawling thing. For birds the larva is the *pièce de résistance*.

The pupa is the resting stage. After having eaten himself into a stupor, the larva builds a cocoon and curls up for a long sleep. Although apparently a stage of complete dormancy, the pupal stage is actually a time of very important and complex metabolic and structural changes, whose end product is the adult.

Very different from the hungry larva, the adult emerges from the cocoon, flies about, mates, deposits her eggs, and dies. Some adults live but one day, some but a fraction of a day. Some have no mouths and cannot eat. Others, such as the ants, live on for several years, working, eating, and hoarding. But whether the female adult lives a few days or a few years, her essential functions are to mate and lay eggs before dying.

Insects are most easily destroyed when in the beginning larval stage or in the molting periods. Eggs frequently escape notice. Adults are tough and may fly about. Cocoons are nearly impenetrable.

Insects cause incalculable damage to forests, to shade and ornamental trees, to cut timber, and even to finished lumber. By defoliating trees, they retard their growth, weaken them, and sometimes kill them. By sucking the sap out of leaves and twigs, they produce the same result. By boring into the limbs and trunk, they weaken the tree to a point where it may be wind-thrown, or, even if it remains standing, become unfit for lumber. Called *vectors,* they serve as carriers of disease, introducing fungi and bacteria into parts where they normally would not have entered. (The infamous Dutch elm disease, for example, is associated with certain bark beetles.)

It should not be forgotten, however, that many insects are helpful rather than destructive: many assist in pollination, many are predators on harmful insects, many are neutral, using the tree merely for a perch or shelter. A program calculated to kill all insects without knowledge of their kind and function is misguided.

One-shot sprays are seldom as effective as a spraying program. On fruit trees, for example, they often result in less fruit than where no spraying at all was done. This is because the spray kills all the predators, all the "good" insects as well as all the "bad" ones, and so permits a second generation of the bad insects to develop free from the check of their natural enemies. Destructive insects, such as the aphids and various forms of scale, usually reproduce much more abundantly and rapidly than do their predators. Hence if both are destroyed at the same time, the destructive insects will reappear first and will remain one jump ahead of the predators until several seasons have gone by and the balance of nature shall have reasserted itself.

The whole economy of nature is so intricately bound up with insects that their sudden destruction would in a few months mean the complete disappearance of many plants, most animals, and, very probably, man himself.

Insects have many natural enemies that under normal conditions keep their numbers more or less constant. Among these are other insects, birds, reptiles, toads, fishes, some mammals, and some fungi.

A certain number of insects is normal. Only under exceptional circumstances do they become epidemic. In urban regions, unfortunately, exceptional circumstances always prevail, since trees are always growing under more or less artificial conditions; hence the need for artificial control is greater.

CHEWING INSECTS

In respect to their methods of feeding, insects are divided into two classes: (1) chewing insects, and (2) sucking insects.

Chewing insects are those that actually chew and eat plant tissue: the leaves usually, but also the flowers, buds, twigs, or even the wood. Although their numbers are legion, common examples are the tent caterpillar, the potato beetle, the cutworm, the bagworm, the grasshopper, tussock moth, webworm, cankerworm, codling moth, leaf roller, leaf miner, sawfly, and so forth.

Since these insects chew up little bits of plant tissue and take them into the stomach, they may be killed premeditatively by spraying the plant with a stomach poison, of which arsenate of lead has long been the most popular. The object of this spray is to deposit a thin coat of poison on all parts of the plant, particularly on both lower and upper sides of the leaves, so that when the insects eat, they will consume the poison This spray may be applied while the insects are attacking the plant or before they invade it. Since it does not kill by contact, its effect is apparent only after a lapse of time (usually 24 to 48 hours after application). If the insects are not eating, as when the bagworms have retired into their bag, the poison will have no effect. Likewise, if the plants are sprinkled with a hose or rained on, the poison will be washed off, and the spraying will have to be repeated.

Although lead arsenate is the most widely used stomach poison, there are others, chiefly arsenate of lime, magnesium arsenate, Paris green (aceto-arsenite of copper), rotenone, sodium fluoride, and pyrethrum. These are sold under a great many different trade names. They should be used strictly according to directions, with particular attention to the amount of dilution, the use or non-use of spreaders and stickers, the compatibility or non-compatibility with other ingredients, and the temperature conditions under which they should be used. Since lead arsenate is poisonous to man as well as to insects, it should not be used where there is any possibility of children chewing or eating sprayed leaves or fruits. All fruits sprayed with lead arsenate must be washed off very thoroughly (usually with a neutralizing chemical) before being eaten.

DDT, chlordane, lindane, and methoxychlor are new organic insecticides which kill both by contact and through the stomach. They promise to supplant in large measure most of the older insecticides. DDT in particular has remarkable residual effects. When mixed with xylene and triton X-100, it forms a spray so powerful that it will kill or paralyze elm bark beetles within a few minutes after they land on a twig even though applied as long as ten weeks before. (See discussion under Dutch elm disease.)

SUCKING INSECTS

Sucking insects are those which, instead of eating the plant, suck out its juices by means of a special beak inserted into the tissues of leaf, twig, limb, flower, or fruit. Common examples are the aphids (plant lice), scale insects, psyllids, mealy bugs, thrips, leaf hoppers, and mites. These insects, although tiny, occur in great numbers, often causing more damage (shown by discoloration, drooping, wilting, or general lack of vigor in the affected plant) than the chewing insects, whose damage although more conspicuous is not necessarily more serious.

Sucking insects are unaffected by stomach poisons because they do not eat the outer surfaces of the sprayed leaves. They must be killed by contact poisons—sprays which by directly hitting the insect's body produce death by burning, paralysis, asphyxiation, or a combination of these. Obviously, contact poisons must be applied when the insects are present, not before or after; also, since most of them have little residual effect, their application must be repeated whenever the insects reappear in considerable number. Application of a contact poison requires even greater thoroughness than applications of a stomach poison; as the sucking insects are relatively stationary, the poison must go to them whereas the chewing insects occasionally go to the poison.

The best-known contact poison for many years has been nicotine sulfate, followed closely by rotenone and pyrethrum (which are also used as stomach poisons), less closely by lime-sulfur, sulfur dusts, potassium sulfide, oil emulsions, and miscible oils.

Each of these materials has its own method of application, its own temperature conditions, its own dangers, and its own idiosyncrasies. Manufacturer's directions should always be followed exactly; even so there are so many details of technique to be followed and precautions to be observed that in no case is it a job for an amateur.

Nicotine sulfate has the advantage of being compatible with lead arsenate, so that both may be applied in the same spray in a double-barrelled blast at both sucking and chewing insects. When nicotine sulfate is used alone, soap is added as a spreader. When it is mixed with lead arsenate, soap must not be used.

Some of the new organic insecticides are very effective contact poisons and are rapidly supplanting, in part at least, the older poisons just named. Some of them, such as DDT, chlordane, lindane, and methoxychlor, are both contact *and* stomach poisons, killing the insects in two ways. Yet they need to be used with considerable care so as not to damage the plants. Lindane and BHC leave unpleasant residual odors and produce off-flavor taste in many fruits and vegetables.

Aldrin and Dieldrin are among the best of these new contact insecticides, although caution is still recommended in their use. Toxaphene is another excellent contact insecticide, although it has been known to produce mild damage on certain plums and avocados. Malathion, although toxic for warm-blooded animals, is a good contact poison which seems to cause only negligible damage to plants. HETP, TEPP, and parathion are too dangerous to be used near dwellings or by inexperienced operators anywhere. Rothane, an analogue of DDT, is a new insecticide which is being used by experimenters with good results.

Red spider, one of the commonest sucking insects, is not a spider at all but a tiny mite. Yet by any other name it would be as harmful, sometimes becoming a serious pest on trees and other plants, both deciduous and evergreen. In hot, dry weather it attacks evergreens with particular severity. Leaves become blotched and yellowish and gradually drop off. The mites may be controlled by washing with a strong stream of water or by spraying with lime sulfur, rotenone, pyrethrum, tetraethyl pyrophosphate, parathion, malathion or a proprietary miticide such as Aramite, Ovotran or Dimite. Dusting with finely divided sulfur is also effective.

BORERS

Some of the most troublesome insects are the wood-borers. There are many kinds of these, some small, some large; some attacking live wood, some dead wood, some both.

Like other insects, borers exist in four different forms: egg, larva, pupa, adult. As adults, most of them are beetles or moths, often quite beautiful and difficult to associate with the eyeless grubs that are the larvae. These are usually white, soft-bodied, strong-jawed grubs that in some species grow to a size of three or four inches. They make excellent fishing worms and form the favorite food of nearly all woodpeckers.

Borers are characterized by the galleries or tunnels they make in the woody part of the tree. Each kind of borer makes a certain kind of tunnel and hence may be readily identified by his work even though he is no longer present, just as a workman may be told by his chips. Some borers work in the heartwood, some in the sapwood, some in the cambium and inner bark. They eat the wood as they tunnel through it, honeycombing it as termites do. Sooner or later most of them eat their way to the outside, making a round or nearly round opening out of which they eject characteristic frass composed of the semi-digested wood that has passed through their alimentary canal.

When they eat the heartwood and sapwood only, their damage is largely structural, weakening the tree to the point where it may be wind-thrown. The secondary effects are sometimes as bad or worse, for by means of their tunnels other insects and wood-rotting fungi gain entrance to the heart of the tree. Carpenter ants are very commonly found in borer holes, enlarging their galleries and preventing healing.

When the borers eat the inner bark and cambium directly, they destroy the vital parts and may kill the tree in short order.

The most important borers, according to the damage they do, fall into two great classes: the *flat-headed* (Buprestidae) and the *round-headed* (Cerambycidae). In one or more of their many forms these borers are found throughout all the United States, attacking nearly every kind of tree. Each species has a particular tree or trees that it prefers. Moreover, each species prefers its wood in a certain condition. On a fallen tree, for example, each part of the log is attacked by different borers: the still living parts by one kind, the recently dead parts by another, the dry dead parts by another, the moist dead parts by another.

Methods of entering the tree vary. So do the types of wounds. Where the larva bores into the wood from the bark, his tunnel usually remains open behind him, and his presence may be detected by exuded frass and, frequently, sap ooze. But there are many other borers that do not make the holes to get into the tree but to get out of it They get into the tree in form of an egg, laid within the woody tissues by the long, thread-like ovipositor of the adult female. The egg hatches into a larva which tunnels about in the wood most of its life, finally making an exit hole so that after pupation (which occurs within the tunnels) the adult which the larva becomes can escape to the outside world. In many cases the adult itself makes the exit hole. Once outside, the adult mates, the female lays an egg in the same or another tree or trees, and the cycle is repeated.

Often the tiny hole made by the adult female's ovipositor heals over, so that there is no way of detecting the presence of these borers until they have made their exit holes and gone. In some cases, however, the hole made by oviposition gradually enlarges, serving as an avenue for the discharge of frass and oozing sap, which at once indicate the larva within.

Borers, like termites, are useful when they confine their efforts to dead trees or dead parts of live ones. But when they attack living trees, as they sometimes do, particularly newly transplanted ones or those weakened by environmental damage or disease, they become a matter of considerable concern.

SYMPTOMS

Borer-infested trees show a gradual or sudden decline in vigor and a thinness of crown. Positive symptoms are circular or elliptical holes appearing on the trunk or limbs with exuded frass and sometimes dripping sap which forms a black or brown stain along the bark.

Very tiny white "worms" often found in infected areas just under the bark are not borers. Nor are the holes made by the sapsucker (woodpecker), which many people mistake for borer holes. The two may be readily distinguished, however, for the sapsucker holes are very shallow and are made in even rows, while the borer holes are deep, irregularly located, and almost always made at an angle, indicating the tortuous nature of the tunnels underneath.

CONTROL

Borers have many natural enemies that help keep their numbers in check. Some borers are predaceous on other borers. Certain ichneumon flies parasitize borers in their larval stage. Other parasites and even diseases afflict them, particularly when their numbers become epidemic. Perhaps their most active and indefatigable enemy is the woodpecker, which with his barbed extensible tongue spears them out of their most secret hiding places.

In the forest we must largely rely on these natural enemies to hold the borers in check. But in cities we may practice our own methods of control.

In the first place all dead trees and dead limbs on live trees should be removed and destroyed to eliminate breeding places for the insects. Cavities should be cleaned out and sealed over for the same reason. The trunks and larger limbs of newly transplanted trees should be wrapped with special tree-wrap paper to prevent egg-laying. Trees weakened by disease or unfavorable environmental factors should be fed and watered to build up their vigor.

In the second place, borers where already present may be attacked directly. Where their presence is indicated by oozing sap or exuded frass, they may be dug out with mallet and chisel. Where their tunnels are open, they may often be impaled on the point of a piece of wire. Where they cannot be reached mechanically they can be killed by squirting carbon disulfide into their tunnels. Where the tunnel leads downward, an oil-can can be used to squirt in the chemical. Where it leads upward, a wad of cotton moistened in the fumigant and thrust into the tunnel is easier. In either case the mouth of the hole must be plugged up *immediately* afterward, for the liquid is so highly volatile that it will dissipate itself into the outside air if not sealed in. For plugging, concrete, asphalt, putty, or moist earth may be used. Since carbon disulfide is a poison, its fumes should not be breathed; since highly inflammable, it should not be brought close to fire; since extremely volatile, it must be kept in a very tightly closed container.

Where borers are very numerous, the tree trunk may be painted or sprayed with an orthodichlorobenzene emulsion, made by mixing 12 parts of orthodichlorobenzene with 1 part of fish-oil soap or common laundry soap and 3 parts of soft water. (Hard water may be softened by adding one teaspoonful of washing soda to each gallon.) This mixture is then diluted in water at the ratio of 1 to 6. It should not be applied to tender branches or to foliage, for it will cause burning.

When borers have affected a considerable area of trunk, it is sometimes better to trace[1] the entire region, cutting away the loosened and damaged bark and then painting the exposed wood with a solution of cottonseed oil and paradichlorobenzene crystals at the rate of 6 ounces for each quart of oil.

Adult borers may be discouraged from laying their eggs by spraying the tree trunks with a 5 per cent solution of DDT at the time the adults are active.

Borers below the soil line (very common in peach trees, for example) may be killed by paradichlorobenzene crystals placed in loosened soil all around the trunk about 2 inches removed from it (but not touching it) and covered with a mound of earth. The crystals should be uncovered in about 10 to 14 days.

Trees particularly subject to borer attack may be protected with a fine wire mesh wrapped around the trunk. This discourages egg-laying and at the same time prevents emergence of adults from any larvae already present.

ANTS

Ants are very frequently found on trees, and one of the commonest questions asked the tree expert is: What harm do they do?

Most of the ants that crawl up and down tree trunks live in the ground, not in the tree. They climb in the tree to milk their aphid-cows (plant lice) and to transfer them from one leaf to another as needed. Wherever large numbers of aphids are found on the leaves, even of the tallest trees, ants are almost always to be found in attendance. Apart from "milking" the aphids and moving them about, they have even been observed to defend them against their enemies. The relationship is an endlessly interesting one. Hence, the harm the ants do is indirect rather than direct. If they were not present, doubtless the aphids would be less numerous.

[1] See discussion of tracing in the chapter Cavity Repair.

There are other kinds of ants, however, that attack trees directly. One of these is the leaf-cutter (*Atta texana*). These ants, living in the ground, cut leaves off trees and carry them to their nests.

Fortunately, these ants are confined to Texas, Louisiana, and other southern states, where their damage is severest on slash and longleaf pine. Where given a chance, they will defoliate rose-bushes with particular relish. In Mexico and farther south, various species of *Atta* become enormously active.

Control is by destroying them in their nests. This can be done by introducing a fumigant, such as carbon disulfide as far down into the galleries as possible, by using a funnel and a length of ¼ inch rubber tubing. With carbon disulfide, all the entrance holes leading to the nest must be stamped shut and kept shut. A chlordane solution poured into the tunnels is also very effective. Chlordane dust sprinkled around the mouth of the holes is also effective.

Carpenter ants are large black ants that tunnel into wood, causing a minor amount of damage. They attack telephone poles, fence posts, structural timbers, cut logs, dead parts on live trees, and occasionally live trees themselves.

They gain entrance into living trees through cavities, unhealed stubs, cracked and unpainted pruning cuts, fire scars, etc. They also frequently utilize abandoned borer holes, cleaning out and enlarging their galleries.

While carpenter ants do not eat the wood, they tunnel away at it to make room for their constantly growing colonies. They actually live in the wood, not in the ground. They are harmful in that they weaken a tree structurally and provide a potential entrance point for other insects and disease-carrying organisms.

These ants can be killed by injecting into their nests carbon disulfide, sodium fluoride, arsenical dusts, kerosene, orthodichlorobenzene, or four per cent rotenone. When the nests are small, the fumigant carbon disulfide is effective. But where they are large and the galleries labryinthine, as they usually are, the fumigants are less effective than poisonous powders, such as sodium fluoride or rotenone, which may be picked up by the ants' feet and tracked to all parts of the colony.

TERMITES

Frequently called "white ants," termites are distinguished from true ants by their white color and thicker waist. They are very interesting social insects that tunnel through wood, actually eating it and digesting it by means of certain protozoa in their intestinal tract. In our country they are found in most of the eastern and midwestern states and all of the southern states, where the problem of their control is greatest.

There are three main kinds of termites: damp-wood, dry-wood, and subterranean, named in reverse order of their importance. The dry-wood and damp-wood termites do not need contact with the ground. The most important kind, the subterranean termites, live in the ground, preferably moist ground, attacking above-ground wood under the shelter of mud tunnels which they build as they go along.

The role of termites in nature is the destruction of fallen logs, in which function they are extremely useful. Sometimes, however, they invade dead parts of live trees or rarely the living tree itself. Also, not being able to distinguish between finished lumber and fallen logs, they attack the wooden parts of houses with such persistency that their control (in the South at least) is a major problem.

In trees termites are most often found in basal cavities. By honeycombing the heartwood they may weaken the tree until it is overthrown by the wind or falls under its own weight. From the heartwood they sometimes work into the sapwood and even into the bark. Sometimes they gain entrance through borer holes, cracked pruning wounds, fire scars, etc. In exceptional cases they build their mud tunnels up the outside of a tree 20, 30, or 40 feet to reach exposed heartwood in a high cavity.

While termites in timbers are controlled by the injection of poisonous liquids, in trees such methods are not possible. The best procedure is to destroy all mud tunnels, clean out and fill all cavities, dig away the dirt a short distance from the trunk, and destroy dead stumps or other inviting dead wood in the vicinity. It is, of course, advisable to destroy the central nest mechanically or chemically, although this is usually too well hidden in the ground to be found.

PILL-BUGS

Pill-bugs, or sow-bugs, are tiny crustaceans, related to the crayfish, not insects at all, but often thought to be by those who do not stop to count legs. They are found in or near damp, rotting vegetation. Particularly prevalent in the South, they do considerable damage to young plants. On trees they are often found under loose bark and in cavities, where the combination of darkness and dampness is ideal for their activities. Like termites, they seem actually to eat wood, sometimes even half-rotten boards. They may be tricked into eating poison bait or sprayed with various burning and repellent solutions.

BENEFICIAL INSECTS

Spiders (not truly insects) do no direct harm, although frequently found on trees and other plants. Strictly carnivorous, they use the plants merely as a place to spin their webs or make their nests. Leaves are sometimes rolled up in a curious manner suggesting the work of an insect; examination reveals a spider inside, safe within his silken nest, waiting for a chance customer. Indeed, by eating possibly harmful insects the spider must be considered a definite asset.

The harvestman, or daddy-long-legs, is often found on plants and under loose bark on trees. It does no known harm to plants; indeed, it is believed by many naturalists to eat plant lice and mosquitoes; hence to be definitely beneficial.

The praying mantis is one of our most interesting and ferocious predators, feeding on live hornets, spiders, grasshoppers, or anything else that comes within range. It is one of the gardener's most loyal friends. All who have seen Edwin Way Teale's classic photographic sequence of a praying mantis fighting a black widow spider will remember it; all who have not seen it should look it up immediately.[2] In Japan the natives tie the mantis to their bedsteads by means of a long, silken leash to defend themselves against mosquitoes.

Ladybird beetles, also called ladybugs and lady beetles, although celebrated in the nursery rhyme that everybody knows, also deserve to be celebrated in a major poem. At least as important as Niagara Falls, Mount Everest, the Grand Canyon, or any other of the various natural wonders that elicit our admiration, they do more toward the control of harmful insects than all the insecticides man has yet compounded. Indefatigable workers, both as larvae and adults, they consume a staggering number of scales and aphids. The most notable example is that of the citrus industry in California, saved from total destruction by the importation of the modest little lady beetle from Australia with no desire for headlines but an enormous appetite for scale. On nearly all trees where scale and plant lice are found, these beetles, in one form or another, are also found.

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[2] *Grassroot Jungles.*

FUMIGATION

Some insects are killed by fumigation rather than by spraying. Commonest fumigants are hydrocyanic acid gas (in the form of sodium, potassium, or calcium cyanide), nicotine (in the form of liquid, powder, or paper), naphthalene (used as a powder on a solid and evaporated slowly over an electric hot-plate or some similar heating device), and sulfur. Of these the first is the most dangerous to handle, and also perhaps the most effective.

Materials used to fumigate the soil are calcium cyanide, paradichlorobenzene, carbon disulfide (sometimes spelled bisulfide), ethylene dichloride emulsion, tear gas (chloropicrin), naphthalene flakes, dichlorethyl ether, and methyl bromide. Of these the only one poisonous to the plants themselves is tear gas, which also happens to be the most complete and effective soil fumigant. Wherever it is used, the soil should not be planted until two or three weeks later. Each of the substances has a special use, a special manner of application, a special dilution, and a special time to be used, according to the plague it is desired to control and the locality in which it occurs. Manufacturers' directions should be followed; county agents can sometimes be of help.

A special use of fumigants arises in connection with borers in tree trunks or limbs. (See section on borer control.)

BANDING

Formerly much practiced, now considerably less so, banding is a moderately effective control measure against certain climbing insects. It consists of placing a ring or band of sticky material around the tree trunk so that insects are trapped in it when they attempt to climb up, just as flies are trapped on fly-paper.

The banding substance is sold under various proprietary names in feed and seed stores, department stores, etc. On trees with thick bark it may usually be applied without bad effects, but when smeared on young or thin-barked trees it has been observed to injure, sometimes kill, them. These bad effects can be obviated by first wrapping the trunk with burlap, then applying the material on this.

The band should be 6 or 7 inches wide, and it should be renewed from time to time as the bodies of the entrapped insects accumulate on it.

Banding is effective only against insects that climb up from the ground, and then not more than 50 or 60 per cent. It is, of course, valueless against flying insects or those that float through the air suspended from silken strands or those that pass from the branches of one tree to another.

Whitewashing tree trunks is also an old-time remedy against climbing and boring insects. It was formerly very widely practiced in this country and is still used to a certain extent. In Mexico it is still almost universally applied to fruit trees and valuable ornamental specimens. Whitewash may be made by dissolving 10 pounds of lime, ¼ pound of salt, and ½ pound of rice flour in 10 gallons of water. Popular belief credits it with the killing of insects in bark crevices. Many entomologists, however, believe it valueless.

IX

DISEASES

Disease is often defined as any departure from the normal. This definition is inadequate, for it leaves out of account (1) the many departures from the normal which confer benefit on the organism; (2) those departures which neither help nor hinder. In the first class we have the mutations that have given us many important varieties of fruits, vegetables, flowers, etc.; indeed, if there were no "departures from the normal," there would be no evolution. In the second class we have those innocent and unexplained modifications of structure or physiology which affect the organism neither favorably nor unfavorably in its struggle for existence—an unexpected difference in texture of bark, color of flowers, shape of leaves, habit of growth, etc. The point to be made is that just because an organism is different from the normal, it is not necessarily diseased. It may be better than the normal, as well as worse.

A better definition for disease is a departure from the normal that affects the organism adversely: weakening its structure, lessening its vigor, or in some way crippling it in the battle for survival. Indeed, the word "disease" carries its meaning within itself: it is a state of being "not at ease", that is, out of equilibrium.

In referring to animal bodies, we may say that disease is accompanied by suffering, but since plants have no nervous system, this term cannot be applied to them. We are thus forced to define plant disease through its manifestations, which are: (1) the dying of tissues, called *necrosis;* (2) the dwarfing or underdevelopment of tissues, called *hypoplasia*; and (3) the overgrowth of tissues, called *hypertrophy* or *hyperplasia.*

Examples of *necrosis* are dead twigs, dead leaves, dead branches, dead bark, dead roots, etc. Examples of *hypoplasia* are chlorosis, or underdevelopment of the chloroplasts in the leaves; small, runty fruit; stunted twig development, etc. Examples of *hypertrophy* are galls, caused by insects or bacteria; burls, which are tumor-like enlargements on trunk or branches; or the leaf-curl diseases, which cause enlargement of part or all of the affected leaf.

In practice it is, of course, more important to recognize a disease than to define it. Even the inexperienced can tell a badly diseased tree from a healthy one: its general look of stuntedness, lack of vigor, sparseness and unhealthy color of leaves are unmistakable.

Unfortunately, however, trees so noticeably ill are often beyond saving. It is much more important, and much more difficult, to detect disease just as it is beginning, at the stage where it is still controllable. Apart from obvious cases of necrosis, hypoplasia, and hyperplasia, other symptoms that help in detection are the fruiting and vegetable bodies of the pathogenic fungi, sometimes quite large, such as the fruiting bodies of the shelf fungi, which may reach a foot or more in diameter; also the bleeding of affected parts, the cracking away of bark, the discoloration of wood, the exudation of gum, the emission of odor, etc.

DIAGNOSIS

To discover the cause of the trouble and to prescribe the remedy are the functions of the diagnostician. The actual application of the remedy is the province of the tree-worker, or dendrician, as he is sometimes called. In most cases, the diagnostician and worker are combined in one individual, particularly in small or medium-sized communities where a higher degree of specialization is not possible.

The diagnostician is the most important man of a tree company's personnel. He should have the widest knowledge, the broadest experience, and the keenest eye. In many large cities the arborist-diagnostician offers a wholly independent service, being equally at the disposition of the homeowners and the tree experts but bound to neither. More often, such services are given by representatives of local or state governments as city foresters, county agents, or state university extension specialists.

In making the diagnosis the following tools will be found useful:

(1) mallet and chisels (½ and ⅛ inch widths) for probing into trunk, limbs, or roots; (2) sharp knife for probing, cutting, and slicing; (3) hand shears for clipping off twigs and leaves; (4) short-handled spade or mattock (army-type) for digging around roots; (5) brace-and-bit for testing trunk soundness and bringing out core sections; (6) hand lens for examining infected parts.

With these simple tools, which can easily be carried about in a car, most of the on-the-spot diagnoses can be made. In the case of obscure fungus or bacterial diseases, samples of the infected tissues should be studied under high-powered microscopes.

AGENTS OF DISEASE

Organisms causing diseases may be divided into three categories: *fungi, bacteria,* and *viruses.* While abnormalities in trees may be caused by such factors as lack of water or change of grade, these are usually considered environmental effects rather than diseases. (See chapter, *Environmental Damage and Miscellaneous Troubles.*)

Similarly, insects, in spite of the great damage they often do to trees, are not considered agents of disease proper. It is important to remember, however, that they are very frequently associated with disease, either as carriers (vectors) or as partners in a symbiotic relationship.

FUNGI

Fungi are plants of a simple order which have no chlorophyll and are unable to manufacture their own food, being dependent upon existing organic matter.

The kinds of fungi that feed upon only dead plants (or animals) are called *saprophytes.* The kinds that feed upon living plants (or animals) are called *parasites.* Some kinds are both saprophytic and parasitic, living on dead tissue until they can contact live tissue.

Examples of *saprophytes* are the fungi that bring about the decay of old stumps, dead limbs, untreated lumber, etc. Like termites, they are beneficial in that they effect a rapid dissolution of dead wood which otherwise would cover the earth in a few years. They are harmful in the sense that they cannot distinguish between wood we have discarded and wood we want to save.

Examples of *parasites* are the fungi that cause Dutch elm disease, powdery mildew, shoe-string root rot, etc. Parasites are legion. There are thousands and thousands of different kinds, all so small they must be studied under a microscope. Ordinarily they escape notice except when the damage they do is serious enough to draw public attention to them, and then it is their effects which are seen and seldom the organisms themselves.

These tiny parasites live upon the leaves, stem, fruit, or other tissues of the host plant, drawing nourishment from it. They produce the various forms of leaf spot, blight, rust, mildew, etc., which are economically of such extreme importance, particularly when they affect cereal plants or fruit trees. They are so small they cannot be dealt with mechanically. Saws, hooks, and shears actually serve to propagate these organisms, for tools used first on an infected tree and then on a sound one serve as a perfect medium for the transmission of disease, unless they are sterilized in between operations.

Fungi are distinguished by their small size, their lack of chlorophyll, their manner of reproduction, and their structure. Although usually very small, they are often quite complex, sometimes existing in two totally different forms: vegetative and reproductive. Examined under the microscope, they are seen to be beautiful and interesting to a high degree. Some of them, however, grow quite large, such as the common toadstools, mushrooms, and shelf fungi, which may exceed a foot in breadth.

Fungi reproduce by means of microscopic spores. These are blown by the wind, splashed by water, and carried by insects, birds, pruning tools, even on the shoes and clothing of tree workers. They enter a healthy tree through wounds or through natural openings, such as the lenticels of the bark and the stomata of the leaves. Some even have the power to penetrate directly the unbroken tissue of leaf blades. Once inside the tree, they rapidly develop into complex, far-reaching mycelial threads, which digest the tree's tissue as they grow into it. When inside, they cannot be affected by any spray applied to the tree's exterior, except possibly sprays containing a chemotherapeutant which may be absorbed and translocated to the infection court.

BACTERIA

Like fungi, bacteria are tiny plants without chlorophyll. (Some scientists believe they are animals.) Unlike fungi, they are all one-celled, dividing by simple fission to form two distinct individuals. Each of these two divides again to form two more, or four in all. Each of the four divides to form eight, etc. Since the division is very rapid, it is possible for one bacterium, if unchecked, to produce thousands or millions in a comparatively few hours. It is the presence of a great number of these tiny organisms in our blood stream or in the plant body that causes disease.

Some bacteria have little tail-like organs (flagella) by means of which they move about in a limited fashion when in liquids. Bacteria have varying shapes; those that parasitize plants are for the most part rod-shaped.

Bacteria are disseminated much as are fungi—that is, transported in the spore stage by wind, water, insects, animals, man.

VIRUSES

Viruses are "ultra-microscopic principles"; also sometimes called "pathogenic particles," "infectious agents," etc., which are the only terms we can use to describe something we cannot see.

Viruses are known entirely by what they do. They are so tiny that none have been seen except through an electron microscope; so tiny that they pass through the pores of the finest filter we can make.

They are responsible for some of our most serious diseases—in animals as well as in plants. They cause phloem necrosis in the American elms, tobacco mosaic, aster yellows, raspberry leaf curl, peach yellows. In man they cause measles, rabies, smallpox, and infantile paralysis.

They overwinter within the tissues of the host plant and can be neither controlled nor prevented by spraying. However, since they are often associated with insects, and since insects often carry diseases from one tree to another, it is probable that control of insects means partial control of viruses.

CONTROL

Tree diseases are controlled by four methods: *protection, eradication, exclusion,* and *immunization.*

PROTECTION

Protection means prevention, and an ounce of prevention is worth many pounds of cure. Certain practices will prevent the onset of disease. Prominent among these is anticipatory spraying, which by killing spores and by covering tree parts with a protective film prevents many diseases from taking hold. By killing insect eggs as well, the spread of disease by mature insects is also avoided.[1] Spraying is discussed in a separate chapter.

Almost equally important is the manipulation of environment to make conditions more favorable for the tree, less favorable for the disease organism, or both.

Trees growing in good soil and receiving abundant water are found to be much more resistant to disease than trees growing in less favorable situations. Hence, the best step in protecting a tree is to improve the soil and to stabilize the water supply.

Similarly, when a tree is ill, the one thing usually recommended for it is food and water. Clearly, however, the same kinds of fertilizer are not recommended for all diseases. Fertilizer high in nitrogenous elements will stimulate trees to outgrow certain diseases, such as most of the cankers. The same materials, however, will make apples, pears, hawthorns, and other trees unduly susceptible to the dangerous fire blight; hence the proper fertilizer in this case is one low in nitrogen and high in potash and phosphorus.

Giving the tree plenty of room to grow also increases its vigor. Trees with crowded top or impaired root system cannot develop properly. Sunlight and air should be allowed to enter as freely as possible.

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[1] Dutch elm disease is one of many serious diseases carried by insects from tree to tree.

Proper pruning increases the tree's resistance to disease. Every dead or diseased limb removed prevents contamination of the others. Removal of rubbing, overlapping limbs prevents the formation of bark wounds. Cutting off jagged stubs closes the door in the face of the enemy. Most fungus spores need to be kept moist for several hours before germinating. The proper opening up of the tree's center and the judicious thinning of too heavy a top allows the sunlight to enter and provides for quick drying of wet branches.

Even cabling may be considered a disease preventive measure, since by preventing breakage of limbs and tearing of bark, it helps preserve an undamaged bark surface.

In short, anything that contributes to keep the tree in high vigor or to keep it structurally intact is a method of disease prevention.

ERADICATION

Eradication means the elimination of diseased parts. It involves the simple sanitary practices of sweeping up and burning diseased leaves, twigs, fruits, etc.; the pruning out of dead and diseased branches, and the removal of incurably diseased trees. It also involves cavity repair, treatment of cankers, and other surgical measures. It further involves spraying where disease organisms are already present. Such sprays are usually dormant or delayed dormant directed at pathogenic spores (such as those causing leaf blisters and anthracnose) which overwinter in bud scales and on twigs.

Programs of eradication, particularly aimed at removal and destruction of the entire tree, are carried out continuously by the United States Department of Agriculture. An excellent example of such a program is the eradication campaign waged against the European larch canker (caused by the fungus *Dasyscypha willkommi*). This campaign, begun in has resulted in the destruction of more than 3,700 diseased larches, thus preventing the spread of the disease to our native stands.

Another form of eradication involves the eradication of alternate hosts. An alternative host is a plant (tree, shrub, or smaller plant) which is as necessary in the life cycle of the pathogen as the tree one desires to save. For example, apple trees are attacked by the cedar-apple rust. The fungus causing the disease spends part of its life on the apple and part on *Juniperus virginiana,* the red cedar. Destruction of all nearby junipers will save the apples. Hence some apple-producing states have a law to that effect.

It is obvious that eradication and prevention overlap in many respects.

Exclusion

Exclusion (actually a form of prevention) is quarantine. It means that plants from an infected area will not be allowed to pass out into other areas. It is obviously effective, although very difficult to enforce.

Many of our tree diseases (and insects) have been imported with logs and lumber. Had exclusion been enforced, we would not now have these diseases. Sometimes apparently innocent ornamental plants are carriers of pathogens that later attack trees.

Quarantine is made harder to enforce because of insects and birds, which carry pathogens from one place to another. However, in many cases strict vigilance has proved effective. To be of value, exclusion must be 100 per cent. In Mexico the black-fly citrus infestation of 1949-1954 was spread all over that country in spite of innumerable quarantine stations because of the slackness of inspection. It was prevented from entering our country only by very rigid controls all along the border.

Immunization

Immunization means two things: (1) the development of disease-resistant strains of plants so that they may be planted in infected areas with impunity; and (2) the use of chemical compounds that act inside the plant to increase its resistance to disease. Until very recently the word was used only in the first sense because direct chemotherapy, although long a theoretic possibility, had stubbornly refused to become fact.

(1) Development of Resistant Strains

Even in the sense of disease-resistant strains, progress has not been very rapid. Although a considerable amount of work has been done in this connection with cereal plants, such as wheat, oats, and others, unfortunately little has been done with trees. The United States Department of Agriculture has been active in discovering trees naturally immune to certain diseases and in extending them into infected regions, but programs in actually breeding resistant strains which hitherto did not exist have been very slow.

Immune varieties are often not so desirable in some other respects, such as size, beauty, shape, etc., as the susceptible varieties. Also, of course, while immune to a given disease, they may turn out to be highly susceptible to another disease as bad or worse. Yet the use of naturally immune trees or the development of new strains of immune ones is often the only recourse in the case of uncontrollable diseases. The most striking example of this is the almost complete destruction of the American chestnut by blight and its gradual replacement by the less desirable, but more resistant, Asiatic chestnuts.

(2) Use of Chemical Compounds

A provocative word in tree care today is *chemotherapy.* Meaning simply "curing with chemicals," chemotherapy is not a new idea, but the recent developments of it are different from anything that has ever been done before. Although work in this science is just beginning, its progress is undeniable, and its promise is enormous. There is hope that trees affected by certain diseases which only a very few years ago were incurable may soon be saved by treatment with the proper chemicals. In fact, commercial work is now being done in this field on an experimental basis.

Curing with chemicals actually occurs every time a pruning cut is painted with wound dressing. It occurs every time leaves are sprayed with copper sulfate and every time roses are dusted with sulfur. Nevertheless, *plant chemotherapy,* as used today, has been given a new and sharp definition: "The control of plant disease by compounds that, through their effect upon the host or pathogen, reduce or nullify the effect of the pathogen *after it has entered the plant.*"[2] (Italics the author's.) Thus the use of chemicals as external protectants is excluded from the definition.

A chemical compound that enters a plant (1) through the leaves by spraying, (2) through the trunk by injection, or (3) through the roots by application to the soil, and is translocated internally to the locus of infection or potential infection where it exercises a therapeutic action is called a *chemotherapeutant.* In contrast, a chemical compound which acts on a pathogen before it has entered the host is called merely a chemical compound (also *protectant*).

Research workers have long been intrigued by the possibility of artificially giving a plant body chemical immunity to disease. If the animal body can be immunized, why not the plant body? The question, although a bold one, was well within the limits of theoretic feasibility, but the practical difficulties in the search for an answer were staggering. For many years attempts were made to immunize the chestnut against chestnut blight (*Endothia parasitica*) and the elm trees against Dutch elm disease. Many cures were reported, but none were verified. Research workers did not despair, however, actively continuing to work on the project at the Connecticut and Rhode Island Agricultural Experiment Stations and later at other laboratories. As results gradually accumulated, chemotherapy ceased to be an ambition and became a fact.

On trees proper the first positive chemotherapeutic results were obtained by Howard against the bleeding canker disease of hard maples, and by Stoddard against the X disease of peaches. The work of these men showed for the first time that trees, like animals, could be made immune to diseases. Extensive and promising experiments have also been conducted against Dutch elm disease.

Although the exact mechanism or mechanisms by which chemotherapeutants produce their effects are not fully known, three modes of action have been described. The first is by counteracting the toxin produced by the pathogenic organism. The second is by acting directly on the pathogenic organism, destroying it or greatly reducing its numbers. Such a chemotherapeutant is called a *systemic fungicide.* The third is by altering the metabolism of the host in such a way that its resistance to the invading pathogens is increased. For example, the Verticillium wilt that affects hops and tomatoes may be reduced considerably in severity by reducing the amount of nitrogen supplied to the plants. Fire blight of pears and other fruit trees is similarly reduced by withholding nitrogen.

As yet no chemotherapeutant has been discovered that renders a plant *permanently* resistant to disease. To give a plant permanent protection, treatment needs to be repeated at regularly defined intervals.

It is believed by many that increased knowledge of toxins and of compounds occurring naturally in plants will make it possible someday to prescribe a specific chemotherapeutant for every disease.

Antibiotics

Antibiotics may be considered as a separate category, or they may be considered as special kinds of chemotherapeutants. In their method of application, in the way they are absorbed, and in their effects, they are for practical purposes identical with chemotherapeutants. In their origin they are different, deriving from microorganisms found in the soil.

The discovery of penicillin focused the attention of the world on the importance of soil microflora. From the humblest of created things, from molds growing in the dirt under our feet, have come discoveries revolutionizing medicine. Stemming from the same source, somewhat the same kind of revolution seems to be impending for plant pathology. Since 1942 more than 3,500 antibiotic materials have been isolated and tested, chiefly for use in human medicine. Of these, fewer than ten have been tested extensively for agricultural use, but from these comparatively few materials some very startling results have developed. The present uses, limited as they are, arouse hopes of a future time when disease may be almost entirely eliminated.

While chemotherapeutants proper have been found effective chiefly against fungi, antibiotics are effective against bacteria. Some kinds of antibiotics, such as antimycin, are effective against fungi. Other kinds, such as endomycin, are both antifungal and antibacterial.

Antibiotic materials are used in quantities so small that a new kind of spray terminology must be employed. Instead of so many pounds per hundred gallons of water, it is necessary to speak of parts per million (p.p.m.). An ounce and a half of antibiotic material dissolved in 100 gallons of water gives a solution containing 100 p.p.m. In some cases the proportion is reduced to the almost unbelievable figure of 1 p.p.m.

Most antibiotic materials are sprayed onto the foliage. Others, such as terramycin applied to peach trees for control of bacterial leaf spot, are injected into the trunk. Materials are absorbed and translocated to the site of the infection or potential infection; hence they are systemic. Antibiotics applied to the soil have yielded negative results: apparently the materials are destroyed or modified before they can be picked up by the roots and translocated.

Good results have been obtained by applications of streptomycin and mixtures of streptomycin and terramycin against blight infections of apples and pears. Streptomycin has also been used against the walnut blight organism. Cycloheximide (Actidione), a byproduct of streptomycin fermentation, has proved effective for the control of cherry leaf-spot fungus. It has also been found to inhibit teliospore formation when applied to cedar-apple galls at 100 p.p.m.

It should not be supposed that all results are positive. Many antibiotics prove ineffective or actually harmful. Certain materials injure the leaves, others produce cracked or discolored fruits. Many otherwise beneficial materials may be ineffective or phytotoxic in improper concentrations.

It is not yet known whether the therapeutic effects are the result of changes induced in the host plant or the result of an accumulation of enough antibiotic materials in the tissues of the host to prevent the pathogenic bacteria from developing.

The duration of therapeutic effects varies according to the disease involved. Experiments with pear blight indicate that the effect did not last as long as 14 days when lower concentrations of antibiotic mixtures were used. On the other hand, the terramycin experiments with peach trees gave control throughout the entire season.

Absorption of antibiotic materials through the foliage is not immediate. Rain falling within a few hours after spray application nullifies or weakens absorption. On the other hand, rain after 24 hours have elapsed has little or no effect.

Experiments are being carried on to determine the effect of antibiotic materials when they are mixed with (1) fungicides, (2) hormones, (3) cuticle solvents.

The price of antibiotic materials for plants is surprisingly low and will doubtlessly go lower as production in mass lots increases. It has been calculated that a tree may be sprayed three times at the rate of five gallons a time for a total cost of fifty cents.

COMMON DISEASES

Some of the commonest and most widely spread diseases are discussed in the pages that follow.

VASCULAR DISEASES (WILTS)

Vascular diseases are so called because the part of the tree directly affected is its vascular system, that is, its sap-conducting vessels. The various kinds of fungi which cause these diseases gain entrance into the sapwood through wounds in the roots, branches, or trunk. They can extend themselves sufficiently in the sapwood to clog up the vessels, preventing sap from rising above that point and thus causing the branches immediately above to wilt. This wilting and curling of foliage is the first indication of the presence of the disease; it is so pronounced that "wilt disease" is often a term preferred to "vascular disease". Although wilting may occur generally throughout the tree, it more often occurs differentially, directly above and on the same side as the infected wound.

Various kinds of trees are affected by wilt. Others are immune. The kind of fungus that attacks one tree does not necessarily attack another kind. Probably the best-known example of wilt is the Dutch elm disease (so called because the disease was first identified in Holland in 1919).

Dutch Elm Disease

Since the unfortunate importation on the East Coast of the fungus *Ceratostomella ulmi* late in the 1920's, the steady spread of the Dutch elm disease, especially across the northern states, has caused alarm throughout much of the nation. In many areas the loss of elm trees by this disease has been as devastating as the loss by hurricane or tornado.

Another importation, the European elm bark beetle, *Scolytus multistriatus*, was already on hand to act as the most important carrier of the fungus from infected trees to healthy elms. Native species of elms in addition to cultivated native and exotic species occur in such abundance that no effective barrier can be set up to halt further spread.

The fungus is carried in the mouth-parts of the spring brood of *Scolytus* when it emerges in early spring and goes to the smaller branchlets of healthy trees to feed on the bark, usually by nibbling in the crotches of the twigs. After infection in the spring, the growth and spread through the sap-conducting vessels is rapid, and by summer whole branches will exhibit sudden wilting of all their leaves followed by browning. Large and vigorous trees may have some resistance to the spread of the disease, extending its progression over two or three years.

Protection of valuable individual trees is secured by application of a dormant spray. In April or at least two weeks before leaf buds begin to break, cover the entire tree thoroughly with a spray containing at least 12 percent DDT. It is extremely important that every twig receive its coating of DDT to prevent any beetle penetration. Trees which receive this heavy dosage of DDT while dormant are customarily not given a June foliar spray, as sufficient protection is carried to the leaf surface against leaf beetle and cankerworm damage. Provision must be made against an increase in mite and aphid attack, by later spraying with miticides and aphicides.

A considerable control of Dutch elm disease is had by the [illegible] removal of diseased trees such as is carried on by local governmental authorities. This program, including [illegible] of all [illegible] from diseased trees, inspection of [illegible]

Plate 15. TREES IN NEED OF CABLING. *Left:* This V-shaped crotch may split in a wind. One cable installed above the crotch will insure against loss. *Right:* Both bracing and cabling are needed here, for day by day the split progresses. Transverse rods through the split portion and one or more cables up in the limbs will save this tree. Without care it is doomed, for the constant movement of the separated parts prevents their natural reunion.

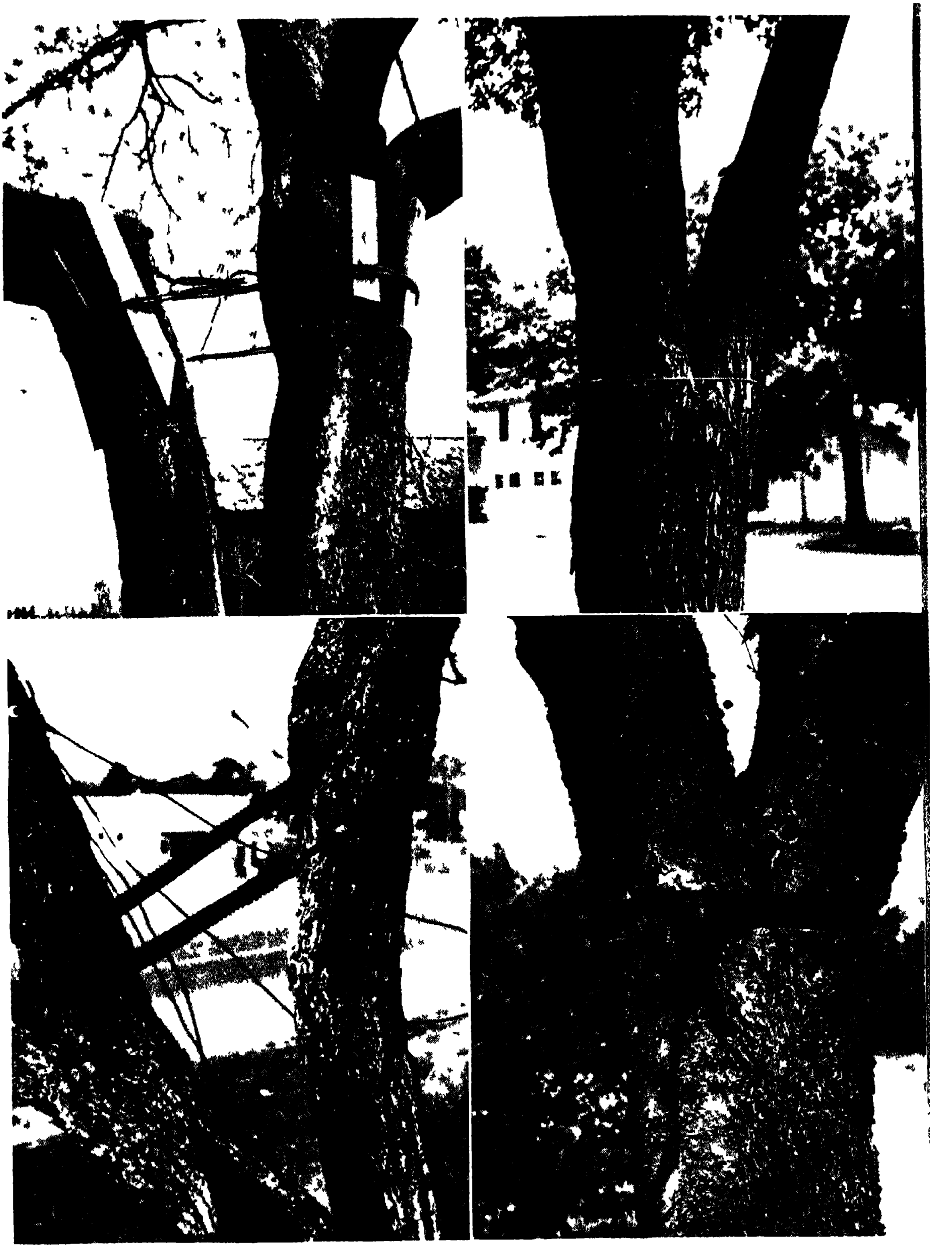

Plate 16 WRONG TYPES OF BRACES *Upper left* Wooden slats soon decay, leaving cables to cut into the tree *Upper right* Iron straps temporarily expedient, eventually kill trees by strangulation *Lower left* This is better since the limbs are not completely encircled But Plate 17A shows a more correct method using lag screw hooks *Lower right* This tree soon died, as the unyielding iron band cut into its circumference.

Plate 17A CORRECT BRACING OF A SPLIT ELM *Left* Threaded rods reinforced by cables higher up *Right* Ends of rods recessed so that new tissue will cover them Setting rods horizontally one third in from each edge will offset sway

Plate 17B *Left* Vertical support for a tree growing almost horizontally over a swimming pool The cradle obviates the need for encircling bands, nails, hooks or wires *Right* Correct cabling The hook is screwed all the way down so that its unthreaded end is against the bark preventing the cable from slipping when slack The axis of the hook is parallel to the axis of the cable for maximum strength

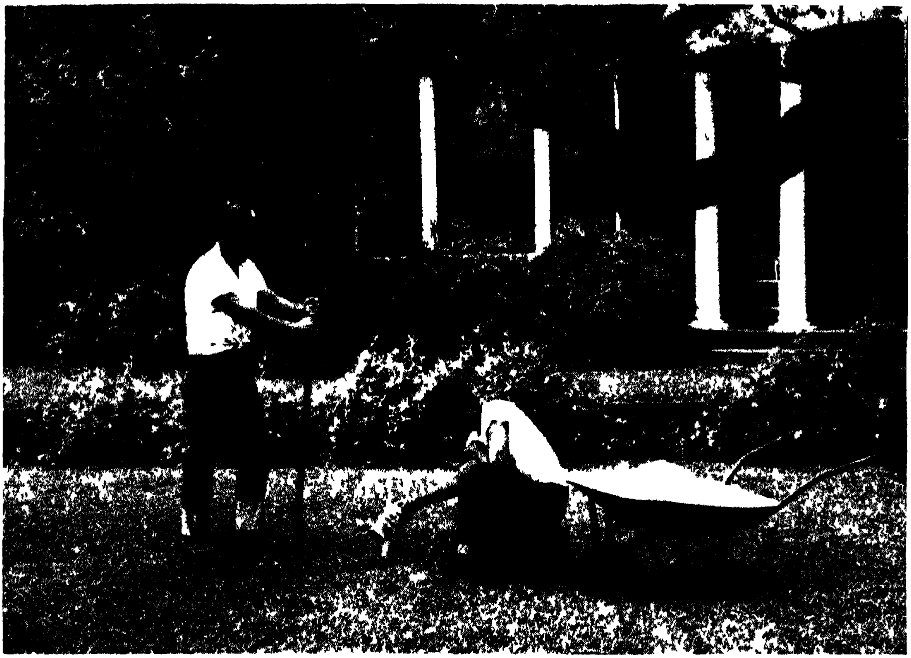

Plate 18A PUNCH BAR FEEDING. Holes 1½ feet deep are made in an area beneath the outer two thirds of the branch spread

Plate 18B Spraying a dormant tree protects it from insects This is best done by a commercial organization able to reach all parts of the tree mechanically. (Courtesy F. A. Bartlett Tree Expert Co)

places where elm wood carelessly stored may release beetles, and similar measures classified as sanitation.

Present research carried on by federal and state agencies of government are along the lines of breeding for natural resistance to the disease and of testing chemicals which might induce artificial resistance. Up to the present time no successful chemical treatment has been found either for protection or cure, although unverified "cures" continue to be reported with great regularity.

Verticillium Wilt

In addition to the Dutch elm disease, Dothiorella wilt and Verticillium wilt also attack elms. The symptoms are similar, the effect less severe.

The Verticillium wilt occurs on other trees as well, particularly on maple. Nearly every kind of maple is susceptible, although the Norway and sugar maples are the most frequently attacked.

The symptoms show up as sudden wilting of foliage on one or several limbs, followed by a gradual extension to other branches. Slime flux often oozes from cracks in the bark. Bright green streaks, gradually turning bluish-black and brown, appear in recently infected sapwood.

The causative fungus is believed to enter the tree through wounds in roots, trunks, or branches. It is probably transmitted from a diseased to a healthy tree by union of the roots. It is known to remain in the soil where infected trees have been removed for a long enough time to make replanting inadvisable. In cases where replanting of the same kind of tree is insisted on, disinfection of the soil with formaldehyde several weeks before is helpful, although not infallible.

Recovery of trees—particularly Norway maples—from mild cases of wilt has been effected by pruning of affected limbs and heavy applications of nitrogenous fertilizer The fertilizer stimulates the rapid formation of new layers of sapwood, which seal in the infected areas.

Digging a trench between an infected and a healthy tree sometimes prevents contamination.

Mimosa Wilt

Another example of wilt is that attacking the beautiful mimosa tree (*Albizzia julibrissin*) (also called "silktree" and "silky acacia"), so widely used as an ornamental in our southern states.

First observed in 1930 in Tryon, North Carolina, the disease has spread rapidly since then through most of North Carolina; into Virginia, South Carolina, Georgia, and other southern states. It was also reported as epidemic in southern Russia in 1920, and a very similar disease of the same tree has been observed on nursery stock in Japan.

The symptoms are sudden wilting of foliage, death of affected leaves and branches, discoloration of sapwood (usually in current annual ring), and finally death of the entire tree. The causative fungus is *Fusarium perniciosum,* believed to be soil-borne.

No control is known. In regions where the disease occurs, no mimosa trees should be planted. Infected trees should be removed and burned.

Oak Wilt

As serious for the oaks as the Dutch elm disease is for the American elms, the oak wilt came into prominence about seven years ago, spreading rapidly through the midwestern states and threatening until very recently the total annihilation of oaks in that area.

A typical vascular disease, the wilt is caused by a fungus, *Chalara quercina,* which grows in the sapwood. All species of oak naturally occurring in the Midwest are susceptible to the disease. In addition, other kinds of oaks not found in this area (such as the southern live oak) have been proved susceptible to the disease when inoculated under laboratory conditions. So far as is known, the pathogen does not attack any other kind of plant except oaks.

Although symptoms vary with the kind of oak attacked, in general they follow the characteristic pattern: wilting and curling of leaves with their eventual death, leaves either falling off or clinging on; diffuse or streaked discoloration in the cambium, showing up as longitudinal streaks when the bark is peeled off a small branch. In a cross section of a diseased twig or branch a brown ring or series of brown spots may be seen in the outer sapwood; these are the mycelium of the fungus, growing in the sapwood and clogging up the water-conducting vessels.

Transmission of the fungus is believed to occur (1) by insects (2) possibly by birds and animals; (3) by root grafts (very common among oaks in a wild state). Fungus placed experimentally on bark wounds has been observed to infect a healthy tree, while fungus placed on uninjured bark produces no effect.

The disease has been controlled locally by eradicatory measures: felling and burning diseased trees and adjacent healthy ones; poisoning healthy trees along the border of infected areas; plowing deeply along the margin of infected areas in order to sever any root grafts. Spraying with benzene hexachloride for control of wound-inhabiting beetles and flies reduces the number of vectors. The fungicide pentachlorophenol may be mixed with the insecticide to help check the development of the fruiting bodies of the fungus. Very recent methods are the aerial spraying of infected areas and direct chemical injection of diseased trees. Although still in the experimental stage, this work is highly promising.

Red and black oaks die more rapidly than white oaks. Diseased white oaks can sometimes be saved by pruning out affected limbs. In regions where the disease is known to occur, pruning of healthy trees should not be done in early spring since the bleeding of pruning cuts which sometimes follows at that time attracts insects which may have just come from diseased trees, bearing with them spores of the fungus.

It is now known that the causative fungus will not live in finished lumber made from infected timber, nor will the fungus itself weaken or deteriorate the timber even though it kills the tree. Diseased trees, however, should be salvaged as soon as possible to prevent deterioration from ordinary wood-rotting fungi.

LEAF DISEASES

Many diseases attack the leaves alone, without affecting woody parts and without entering the vascular system. These are much less serious than root rot, phloem necrosis, wilts, cankers, etc., but they often sharply retard the growth of the tree, lower its vigor and consequently pave the way for the inception of a worse disease.

Leaf diseases are caused by bacteria or fungi, which are transported in the spore stage by wind, water, and insects. They may grow entirely on the surface of the leaves, or they may penetrate the inner tissues and draw out the juices with little sucking organs. They spread most during hot, humid weather when little wind is blowing to dry the plants. They overwinter in dead leaves and fruit, in cracks along the bark, and in tiny crevices in the ground.

Sanitation, meaning the immediate removal and burning of dead leaves, twigs, branches, and fruits, is important in their control. Preventive spraying is equally important. Some of the commonest kinds are discussed below

Leaf Spots

Leaf spots are irregularly shaped spots or marks of discolored or dead tissue on the leaf caused by many different kinds of fungi. When the area involved is large with indefinite margins, the disease is sometimes called "blight" or "blotch." Leaf spots usually have a dead center of one color surrounded by a dying area of another color. Small black dots on a spot are fruiting bodies of the fungus; their absence may mean that they have not yet formed, or it may mean that the spot is of bacterial rather than fungus origin.

Leaf spots are ordinarily of little importance. A certain number occur on all trees at all times. It is only when this number becomes excessive that harm may be done. Under exceptional circumstances they may cause entire defoliation, thus lessening the resistance of the tree to other diseases.

Whenever it is possible to separate spotted leaves from the others, they should be swept up and burned. If added to the compost heap, they constitute a source of inoculum for the following year.

Spraying with Bordeaux mixture in the spring as the leaves unfold is a preventive. Sometimes several subsequent sprayings are necessary. Sulfur sprays and dusts and copper-lime dust are also used. Captan is a new fungicide that has been found effective. Control of spots is usually more important on fruit trees than on shade trees.

Sooty Molds

Sooty molds, or sooty fungi, cover the leaves of many plants with a black, sooty coating during midsummer. The causative fungi are closely related to the powdered mildews but distinguished from them by having dark-colored mycelium instead of white.

Rather than invading the inner tissues of the leaf, these fungi grow along the surface, feeding on sugary exudations from the plant or on secretions from attacking insects, principally plant lice (aphids) and white fly. Hence they are not parasitic, although they may harm the plant by shutting out sunlight and preventing photosynthesis, just as soot from factories does.

Where serious, the molds can be washed off by a strong stream of water, rubbed off by hand (on small plants), or sprayed with Bordeaux mixture or dritomic sulfur. Simultaneous spraying for control of the accompanying insects is also necessary.

Powdery Mildew

Powdery mildew is much like sooty molds, except that it forms a white covering over the leaves, rather than a black one, and it actually penetrates the leaf tissues with root-like sucking organs.

It is more common on small plants, such as roses, phlox, lilac, and crape myrtle, than on trees, although under exceptional conditions it may occur on these. It causes curling, dwarfing, and death of young, succulent growth, but seldom affects older leaves.

Spores are wind borne. Preventive spraying with dritomic sulfur or dusting with fine sulfur will give easy control. Raking and burning leaves in the fall is also recommended.

Scab Fungus

Scab fungus is a serious disease of fruit trees, particularly apples, and a disease of lesser severity on some shade trees, particularly willows, in certain parts of the country. It produces definite, nearly circular, slightly raised lesions on the underside of leaves, particularly along the veins and midrib; sometimes also on fruits and twigs. On the apple it may cause loss of from 50 to 100 per cent of the crop, and by injuring the leaves it reduces the possibility of next year's crop.

The fungus overwinters on dead and injured twigs and in shed leaves and shed fruits. In the spring the spores are carried by the wind to the developing leaves.

Where serious the disease needs a more or less continuous program of spraying: an application of Bordeaux mixture or dry lime-sulfur just as the leaf buds are opening and successive sprayings as needed to prevent secondary infection. Burning of diseased leaves, twigs, and fruits is essential.

Leaf Cast

Leaf cast of conifers (also called *needle cast* and *leaf browning*) attacks such conifers as pine, fir, spruce, larch, juniper, and hemlock. It is caused by several different kinds of fungi, each one usually partial to a certain kind of tree. This trouble has been confined to forested areas, doing little damage to the coniferous ornamentals.

Yellow or brown spots or bands form on the needles, followed by the fruiting bodies in the form of black pustules. The entire leaf gradually browns and falls off. Even small twigs may be killed. In some cases only the current growth is attacked; in other cases it is the older growth that is infected. Spraying with Bordeaux mixture is recommended. Young trees seem to be more susceptible to infection than older ones.

ROOT DISEASES

Some of the most difficult diseases to diagnose and to control are those that attack a tree's roots. Since these develop mostly underground, they are usually not noticed until they have become well established. Treatment is naturally more difficult, owing to the problem of excavating large amounts of soil and of discovering all infected root areas.

Cotton Root Rot

In the Southwest probably the most serious root disease is cotton root rot. (Also called Texas root rot and Phymatotrichum root rot.)

This is caused by a soil-inhabiting fungus (*Phymatotrichum omnivorum*), which gets its common name for its frequent attacks on cotton and its specific scientific name for its omnivorous ability to attack over 1,700 known other plants. Only the monocotyledons and some of the crucifers, mints, and verbenas are known to be immune.

Infected plants suddenly turn yellow, wilt, and die. If the infection is noticed in time, the plants may sometimes be saved by heavy applications of ammonium sulfate to the soil. But once the infection has progressed past a certain point, remedies are unavailing.

The fungus spends most of its time under ground, overwintering in the form of sclerotia. During periods of abundant summer rains, masses of fungus mycelium may appear on top of the ground.

Soil can be disinfected with formaldehyde or carbon disulphide although these should not be used in the vicinity of growing plants.

Shoe-string Root Rot

Another very serious root disease spread more generally over the country is shoe-string root rot. (Also called crown rot, mushroom rot, and Armillaria rot.) Almost as omnivorous as cotton root rot, this disease is known to attack oaks and maples principally; birch, black locust, apple, larch, chestnut, mountain ash, pine, spruce, poplar, and sycamore less frequently.

The causative organism is the fungus *Armillaria mellea,* which has the quality of being either parasite or saprophyte as conditions demand. This means that it may live on dead stumps and dead roots, or it may attack directly a living tree. Spores of the fungus gain entrance into a live tree through wounds in roots or in lower trunk. Once the mycelium has developed (either on a live tree or on a dead stump), it sends out long, black strands ("shoe-strings") that grow through the soil to contact healthy roots of adjacent trees, penetrating and infecting them. Thus the fungus rapidly extends itself, traveling through the air by wind-borne spores and through the ground by the black, snaky strands. Caught by this two-fold attack, whole stands of trees are sometimes wiped out.

Symptoms are difficult to distinguish from symptoms of other diseases, particularly from those of illuminating gas injury. In cases where the progress of the disease is rapid, the leaves wilt suddenly and become dry. Where the progress is slower, the whole top shows a decline in vigor, the foliage becoming scanty and the branches dying one by one.

The surest diagnosis is made by examining the main roots or the base of the trunk at the soil line or just under it. Where the disease is suspected, the bark should be cut away. If the fungus is present, it will appear as a felt-like white mass closely appressed to the sapwood. Where the tree is affected on one side only, the fungus will be found on that side. Where the entire top has died, the fungus will be found in complete encirclement.

When the disease has gained a good start, the tree usually cannot be saved. If the diseased roots are few, they should be cut back to sound wood, the affected region of trunk chiseled and scraped back to healthy tissue, and all cut surfaces shellacked and painted with an antiseptic wound dressing. Soil should be dug away from the affected area to allow free entrance of sun and air. The tree should be abundantly fed and watered. To reduce the possibility of further spore infection, the mature fruiting bodies (appearing as honey-colored mushrooms) should be destroyed, although in city conditions they rarely appear.

Badly diseased and dead trees—including as much of the root system as possible—should be removed and burned. If another tree is to be planted in the same hole, the soil should be thoroughly sterilized with formaldehyde or carbon disulfide, or, better still, dug out and replaced.

To prevent underground attack from the fungus strands, a circular trench one foot wide and two feet deep should be dug around the infected tree. All roots within the trench—both from the diseased tree and the nearby healthy ones—should be cut off and painted over.

Fortunately the disease does not ordinarily attack trees in high vigor. Those weakened by fill, lack of water, lack of food, insect depredations, or any other cause are its chosen victims. Hence the best preventive measure is the maintenance of vigor by prudent care and adequate feeding and watering.

Recent work by the Connecticut Agricultural Experiment Station shows that phenyl mercury acetate applied to the soil (at the same strength usually recommended as a leaf spray) will in some cases control Armillaria rot.

PHLOEM NECROSIS

Phloem necrosis is a very serious virus disease that injures or kills the bark and consequently the tree itself. In the last twenty years it has caused severe losses among the American elms in the central and lower Ohio River watershed. The disease was first identified as a virus disease in 1938, although reports indicate that it was prevalent in parts of Indiana, Illinois, and Kentucky for many years before this date.

Symptoms are first noticed as a thinning and yellowing of foliage. Leaves curl upward along the edges, making them seem narrower and making prominent their lighter-colored under surface. Gradually the leaves turn from yellow to brown and then fall off or hang on in small dry bunches.

Positive diagnosis can be made by examining the phloem (inner bark) and cambium. The phloem shows characteristic discoloration: yellow or golden, flecked by brown or black specks, later turning dark brown and necrotic.

Moderately discolored phloem possesses a faint odor of wintergreen, which may be more readily observed by enclosing a small piece for a short time in a stoppered container. The discoloration and wintergreen odor of the phloem are unknown in any other tree disease. The affected phloem is usually found in the root buttresses and lower trunk, less commonly in higher trunk and branches.

No cure or control of phloem necrosis is known. Perhaps resistant strains of trees can be developed. Until that time comes, no elms should be planted in areas where the disease occurs. In other areas it is not wise to plant elms—or any other tree—in exclusive stands, for an epidemic will destroy all. The planting of as many different kinds of trees as possible is highly advisable.

ANTHRACNOSE

Anthracnose (also known as "blight") is a leaf and twig disease, caused by various kinds of fungi (most of which belong to the genus Gloeosporium). Among the many different kinds of trees attacked are maple, sycamore, ash, elms, poplar, walnut, butternut, hickory, linden, willow, horsechestnut, beech, oaks, cherry, and plum. Usually each kind of fungus has a preference for a certain kind of tree, although all produce nearly identical symptoms. The disease is especially severe on sycamores.

The symptoms show up as brown, reddish-brown, or purple spots on the leaves, particularly along and between veins. The spots gradually extend until they coalesce; then the leaf turns brown and falls off. Twigs are also attacked, particularly on the sycamore. Small cankers form, gradually enlarging until they girdle the twigs. Above the affected area the twig and its leaves die. Diseased trees show many of these dead twig tips, contrasting sharply with adjacent healthy foliage. Later as the disease spreads, the whole top becomes brown.

In severe cases the tree may be entirely defoliated. If the tree has strong recuperative power, new leaves come out, but they too may be destroyed by secondary infection. Repeated defoliations and extensive twig die-back disfigure the tree and weaken it to the point where insects or other diseases may find it easy prey. Mild cases usually need no control. Severe cases should be attended to.

Control is by spraying and sanitation. Since the fungus overwinters in fallen leaves and twigs, these should be raked up and burned. Infected twigs that do not fall off should be pruned off and burned. In the South the fungus also overwinters in the spore stage on dormant buds. These may be disinfected by a dormant spray composed of one part of lime-sulfur diluted in ten parts of water.

To prevent infection from neighboring trees, the leaves should be sprayed just as they first appear with a copper sulfate solution, or organic mercury formulations. Where epidemics are present, they should be re-sprayed with the same solution every 10 to 14 days, according to conditions. The disease is worse during periods of cool, rainy weather.

A badly infected tree should be fed and watered liberally to help it make a rapid recovery.

WITCHES' BROOM

Witches' broom is so called because its chief symptom is the production of many small, closely bunched adventitious branchlets at or near the tips of twigs. It is a disease caused by such different things as viruses, fungi, mites, and dwarf mistletoe.

It is known to occur chiefly on hackberry and larch, less commonly on serviceberry, honey locust, hickory, birch, butternut, pine, fir, spruce, and hemlock.

Damage is ordinarily small. The buds that give rise to the deformation are infected at varying times, so that control by spraying is very difficult. Pruning off the infected area down to sound wood is the only recommended procedure.

Fire Blight

Fire blight is known to every orchardist as one of the most troublesome diseases of apple, pear, and quince. Less well known is the fact that it also attacks many ornamental trees and shrubs, particularly those of the Rose family. It has been found on English hawthorn, mountain ash, flowering plum, flowering quince, cotoneaster, cockspur thorn, pyracantha, serviceberry, Christmas berry, rose, spirea, and others.

The disease makes itself known by a sudden browning or blacking of flowers and leaves near the twig tips, making the tree look as if scorched by fire, whence the name. The twigs, and occasionally larger branches, die. Sometimes large cankers develop on main limbs or trunk, in which the pathogenic organisms conveniently overwinter. On some plants, such as the flowering quince, the disease affects only the blossoms.

The disease is caused by the bacterium *Erwinia amylovora*. Bacteria are carried by splashing rain, bees, flies, and other insects. Infecting blossoms in the spring, they are rapidly transmitted from one tree to another. From the blossom they travel downward into fruit spurs, twigs, and even the larger branches.

Use of nitrogenous fertilizer on pear trees stimulates the growth of new, tender shoots which are very susceptible to blight. Hence such fertilizer should be used sparingly; similarly severe dormant pruning should be avoided.

Control is achieved by pruning and spraying. All diseased twigs should be cut off several inches below the affected area, and pruning tools should be thoroughly sterilized in denatured alcohol or some other solution before using again. Cankers can be treated surgically if not too extensive. This is done by chiseling out the affected portion and painting the sound wood with bichloride of mercury, followed by antiseptic tree paint. Where cankers nearly girdle a limb, it is better to remove the limb. Seriously cankered trees are better destroyed.

Some cankers may be cured by painting over without need of excavation. A good chemical paint for this purpose is made of cobalt nitrate (3⅜ ounces), commercial glycerine (1.7 fluid ounces), oil of wintergreen (3.4 fluid ounces), acetic acid (1.7 fluid ounces), and ethyl or denatured alcohol (27.2 fluid ounces).

Spraying of blossoms just as they are entering the full bloom stage with a 1–3–50 Bordeaux mixture or with a copper-lime dust is recommended. In severe cases two sprayings may be necessary.

Recent developments in the use of antibiotics have shown that agrimycin (a mixture of streptomycin and terramycin) will greatly reduce blight infections on apple and pear. An experiment in 1954 in Marysville, California, demonstrated that agrimycin applied as a spray on 600 Bartlett pear trees reduced the disease to one infection every six trees as contrasted to nine infections per tree in the check plot.

Galls

Galls are globular, semi-globular, or cylindrical swellings produced on leaves, petioles, or twigs by the "sting" of parasitic wasps, or by midges, aphids, or other insects, or by the infestation of bacteria or fungi.

Each gall is characteristic of the insect or bacterium or fungus that causes it; and of all the thousands of different kinds of galls, no two kinds are alike. The gall is actually a part of the plant; it is composed of plant tissues and is alive only so long as the plant is alive—plant tissues diverted from their normal development and forced to serve the ends of the parasite.

The galls or tumors on the stems of such plants as blackberries and roses are caused by bacteria. In the cedar-apple rust the so-called "cedar apple" is a single cedar leaf enlarged and deformed by the fungus *Gymnosporangium juniperi-virginianae.*[3] The plant lice called phylloxera are responsible for the leaf galls on grapes and on certain shade trees. Gall-forming midges usually attack herbaceous plants, such as chrysanthemum.

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[3] Recent work has indicated that one of the antibiotics, cycloheximide (Actidione), will inhibit teliospore formation of the fungus when applied at a concentration of 100 p.p.m.

The greatest majority of shade tree galls are caused by egg-laying insects, especially the tiny wasps. They are, if not most common, at least most noticeable on oaks, where they sometimes take the form of balls an inch or an inch and one-half across hanging from almost every twig or leaf. On certain days of the year small wasps may be seen visiting the oaks, busily engaged in piercing leaf or twig and depositing their eggs inside. The presence of the egg causes a diversion of plant juices to that point and an overgrowth of tissues, resulting in the gall. As the eggs develop, the gall enlarges. Inside it the larvae hatch and are nourished and housed until their destiny calls them to break open the gall and depart. No cosier or safer home could be imagined. The gall provides protection, concealment, retirement, food, and lodging. It is a highly successful mechanism; hence so many different kinds of insects make use of it.

On hackberries and cottonwoods the galls are usually found on the petioles. On oaks they are usually found on the leaves. Nearly every kind of tree is subject to some kind of gall, and a thorough study of the gall-tree relationship is itself a subject for a long and bulky volume.

Ordinarily, on shade trees, galls do no discoverable harm to their hosts. Although the relationship is one of parasite to host, the parasite in this case has been lucky enough or wise enough not to kill the goose that lays the golden egg. The perfect parasite is the one that draws what it wants from its host while allowing it to live on comparatively unharmed. This most gall-makers have done.

Many people believe the gall is a dangerous disease, resorting to desperate remedies to control it. Sometimes they have the affected tree cut down, under the illusion that they are protecting their other trees from infections; sometimes they have it topped, "to give it a fresh start"; most commonly, they have it sprayed.

An understanding of the origin and nature of insect galls will convince one that topping and felling are useless, since the causative insect may fly to the tree from any point of the compass. Spraying is similarly of no value, for the adult insect may come at the time least expected, so that in order to destroy it, the tree would need to be sprayed almost continuously 24 hours a day over a period of several months; while to the egg or larva inside the gall, spraying means no more than rain means to a man inside his house.

Some kinds of galls have been found useful to man, particularly the kind occurring on a species of oak (*Quercus infectoria*), found in Asia Minor, Persia, and Syria. From these galls, called "oak apples," "gall nuts" or "nutgalls," tannin and gallic acid are extracted, used in tanning, in dyeing, and in the manufacture of ink. Galls are among the most powerful of vegetable astringents and are also used in medicine.

While the majority of insect galls are nothing to be alarmed at, bacterial and fungus galls may be more harmful. The most serious of these is crown gall.

Crown gall is a bacterial disease that causes tumors or gall-like swellings on the roots or on the trunk near the base on such different trees and shrubs as apple, pear, plum, quince, flowering almond, cherry, sycamore, poplar, maple, willow, juniper, English walnut, chestnut, Arizona cypress, incense cedar, yew, oleander, and euonymus.

The disease is caused by the bacterium *Pseudomonas tumefaciens*, which gains entrance through wounds in the bark. Rather than killing the tissues affected, the bacteria cause them to hypertrophy. Growth may be retarded, foliage may turn yellow, roots and branches may die. Although no great harm is done on older trees, young trees are sometimes killed.

The only control is prevention. Newly set out trees should be inspected for signs of galls on stem or roots. Precautions should be taken to prevent wounding tender bark. Wounds made by the lawnmower in cutting grass are often a focal point of infection. Where the disease is known to be prevalent, only nonsusceptible varieties should be planted.

BURLS

The discussion of galls naturally leads us to burls, which are another kind of deformation or hypertrophy of tissue, occurring on the trunk or major limbs of a tree rather than on the twigs and leaves. But while the gall is caused by insects or bacteria, the cause of the burl is still obscure.

Specifically, burls are large, globular or semi-globular swellings found at some point along the trunk, often near the bottom, and less frequently on the large limbs. They develop very slowly, growing as the tree grows, and attaining sometimes twice or thrice the size of the trunk. Solid and woody, they are actually a part of the tree, not a growth from the outside. They do no apparent harm, for affected trees live many years, up to what seems to be their normal life span. The interesting thing about burls is that the grain inside them is fantastically curved and twisted, in such a manner that they are highly prized by cabinetmakers for use in their most exquisite pieces. Burls occur on such different trees as oaks, elms, mesquites, walnuts, etc. A black walnut with a well-developed burl is extremely valuable for the beauty of its wood.

Anyone with a burl on his tree need not worry about it. As far as we know, it is harmless, and it is certainly not contagious. Under no circumstances should the amateur be allowed to attack it with chisel and mallet, for the attempt to cut off or chisel out these excrescences will do more harm than good. Since the original cause of burls is possibly mechanical wounding, then amputation or excision is certainly useless.

CANKERS

While burls are not serious, cankers definitely are. They are caused by a number of different fungi, and they assume different shapes, according to the kind of tree they affect. They weaken and disfigure the parts they form on, sometimes killing only the affected limbs, sometimes the entire tree.

Cankers usually appear as sunken, deformed areas on limbs or trunk, often bleeding, sometimes dry. Examination often shows successive layers of dead callus radiating from a center, indicating the yearly attempt of the tree to grow over the infected region and the gradual spreading out of the infection into the adjacent healthy tissue.

Cankers damage the tree by killing the tissues they are in direct contact with, usually the bark, cambium, and sapwood, and by interfering with the flow of nutrients through the affected region. A canker on a limb will cause it to wilt and die, by gradually shutting off its food supply, but will not affect the rest of the tree unless it works down internally to other parts. A canker on the trunk is more dangerous, since it reduces the food supply to the entire crown, causing leaf drop, wilting, die-back, and, if unchecked, eventual death.

The causative organisms are usually wind-borne, gaining entrance into the tree through old stubs, open cavities, unpainted pruning cuts, split bark, and mechanical wounds. The disease is usually well-established before the symptoms appear. In regions where the pathogenic organisms are present even the slightest wound may prove an entrance point: a careless saw cut, a rope burn, a knife thrust, an accidental blow by the lawnmower. The disease has been experimentally transmitted to a healthy tree from an infected one by use of unsterilized pruning saws and by tree paint that did not contain an antiseptic ingredient.

Exceptionally vigorous trees sometimes outgrow the disease. Where damage has not progressed too far, affected limbs may be cut off and burned. If on the trunk, main root, or main limb, the canker may be treated surgically. Trees too far gone should be cut down and burned.

Surgical treatment means the excision of the infected area, including enough adjacent sound tissue to insure complete eradication; swabbing of exposed wood with corrosive sublimate; and covering of the whole area with an antiseptic and waterproof wound dressing. All chisels and other tools used in this operation should be sterilized immediately after use by washing in denatured alcohol. A surgically treated limb may be weakened to the point where it needs braces. Diseased trees should be fertilized and watered abundantly to hasten callus formation over the affected area.

Recent work in chemotherapy gives hope that some day the cankers may be controlled chemically. At the present time the only significant chemotherapeutic cure is that of the bleeding canker on maples.

Nectria Canker

Some of the most widespread cankers are those caused by species of the fungus *Nectria*. There are many of these species, attacking nearly every kind of hardwood and some of the larger shrubs. The fungus is wind-borne, entering the tree through wounds, insect injuries, frost cracks, etc.

The most usual form assumed by the cankers is that of an open pit showing successive layers of destroyed callus tissue around it, in the form of concentric circles. Because of this appearance, it is sometimes called target canker; on birches it is called European canker. At certain times of the year small scarlet or reddish-orange pustules (fruiting bodies) are found on the newly killed bark along the edges of the canker.

The birches seem to suffer most from this fungus. Other trees are seldom killed, although their vigor is reduced and the way is opened for other infections. Maples often outgrow the disease, particularly if given nitrogenous fertilizer.

Sphaeropsis Canker

A number of different kinds of fungi belonging to the genus Sphaeropsis cause cankers on both evergreen and deciduous trees. These fungi usually attack only those trees previously weakened by other disease or unfavorable environmental factors. Among evergreens the pines, particularly the Austrian, Scotch, Mugho, red and white pines, and the Douglas fir and blue spruce are victimized by the disease. Among deciduous trees the American elm and some of the oaks are the most common victims.

On evergreens, symptoms show up as wilting and browning of foliage at the twig tips and deposits of resin along twigs. The lower branches are the most seriously affected. Examination of the needles, twigs, and cones reveals the pin-point, black fruiting bodies characteristic of this fungus.

On deciduous trees the dying and browning starts at the top and gradually works downward. Dark-brown or reddish-brown cankers develop on the bark, the wood underneath taking on the same discoloration.

Chestnut Blight

Called "blight" because of its rapid killing action, this disease is really a canker. It is caused by a parasitic fungus (*Endothia parasitica*) which kills cambium and bark on chestnut trees.

Introduced into our country from Asia in the early 1900's, the disease has virtually wiped out the stands of native chestnut in the eastern United States. The loss of the chestnuts is probably the major tragedy of our American woods. The rapidity, completeness, and virulence of the disease's spread is without parallel in the history of our forests. Hope may be taken from the fact that old stumps continue to throw up vigorous new shoots which sometimes attain considerable size before the blight attacks and kills them. Experiments are being carried on to find disease-resistant varieties. Chinese and Japanese chestnuts, although much less valuable trees, have proved highly immune.

First symptoms are a sudden browning and wilting of part or all of the tree's top. Examination of affected limbs shows the presence of girdling cankers, which take the form of discolored, sunken areas along the bark. When the bark is peeled off, yellowish or reddish wefts of fungus tissue are found beneath. Tiny fruiting bodies dotting the affected bark are sometimes visible. When the canker is on a limb, only the distal parts of that limb are killed. When on the trunk near the bottom, the whole top is killed.

Spores, ejected in great numbers, are carried by wind, insects, birds, and water to wounds in other trees. No control method has been discovered. The same fungus has been found growing with lesser effect on chinquapin (*Castanea pumila*), staghorn sumac, shagbark hickory, red maple, and some of the oaks.

Cytospora Canker

Several species of the fungus *Cytospora* produce disease on both evergreen and deciduous trees. Among evergreens the Colorado blue spruce and the Norway spruce are most commonly affected; Koster's blue spruce and Douglas fir less commonly. Symptoms are browning and dying of needles, almost always accompanied by copious exudation of resin at various points along the twigs.

(Hence the disease is sometimes called *resinosis.*) By cutting into the affected area at the point where it joins healthy tissue, cankers with their black, pin-point fruiting bodies can be discovered. Branches are affected differentially, the dead ones often lying in close proximity to the live ones. Dead and diseased branches should be pruned out as soon as they appear, although pruning should not be done in wet weather, at a time when the spores are most easily spread. The making of wounds, even the tiniest, should be very carefully avoided.

Deciduous trees attacked include peach, willow, elm, the Carolina and silver-leaf poplars, and others. Being both saprophytic and parasitic, the fungus frequently bides its time living on dead branches until the appearance of a wound in live tissue affords it an entrance point; hence the importance of periodically pruning out dead wood.

Cankers usually appear first on twigs. Gradually the fungus travels down the stem, invading larger branches and eventually the trunk. Cankers on the trunk appear as brown, sunken areas frequently covered with red pustules. Wherever girdling takes place, the parts above that point die.

Cytospora usually attacks trees whose vigor has been weakened by some other cause. Correction of the environment accompanied by adequate fertilizing and watering will eliminate the predisposition.

Planetree (Sycamore) Canker

The widely planted London plane, and to a lesser extent the sycamore (buttonwood), is attacked by a canker-forming fungus *Ceratostomella fimbriata.* Many thousands of planetrees have been destroyed along the Atlantic seaboard since 1929. Worst of all, the disease seems to be spreading westward slowly, although it has not yet passed the Alleghanies (chiefly because most of the London planes are confined to the eastern states).

The fungus gains entrance through pruning wounds, insect wounds, frost cracks, etc. It is also transmitted in tree paints that do not contain an antiseptic ingredient.

When the fungus enters the tree, it grows towards the center. From the center it grows out radially along several lines, forming cankers where it reaches the bark. A stricken tree shows greatly reduced foliage, followed by death of affected limbs, or of the entire tree if the canker is on the trunk. Trees may live one to five years after the appearance of the canker.

Wood underneath the cankers is characterized by bluish-black (sometimes reddish-brown) streaks. A cross-section of the wood shows the bluish-black streaks in the form of wedges with the apex at the center.

No control is known. Infected trees should be cut down and destroyed. In regions where the disease is known to occur, plane owners should be particularly careful not to wound trees and should allow none but arborists of proven competence to work on their trees. Planting of solid stands of planetrees within a small area should be avoided, as predisposing to the spread of epidemics.

Norway Maple Canker

This disease, which has destroyed hundreds of Norway maples since first observed in 1918 or 1919, is caused by the fungus *Phytophthora cambivora.* The disease is described as follows by P. P. Pirone, who first isolated the fungus from a host plant in the United States:

> An early symptom is a thin crown resulting from a decrease in the number and size of the leaves. Trees die within a year or two following this period of weak vegetative growth. Another, more striking symptom is the presence of cankers at the base of the trunk near the soil line. The inner bark, the cambium, and in many instances the sapwood are reddish brown in the cankered area. Death occurs when the entire root system decays or when the cankers completely girdle the trunk.[4]

Infection is believed to occur through wounds. Trees in poor vigor or in poorly drained soils are abnormally susceptible.

No cure is known. Dead and diseased trees should be cut down and burned. Trees should be planted only in rich, well-drained soil. Existing trees should be protected against wounds, particularly near the ground line.

Bleeding Maple Canker

This disease is caused by *Phytophthora cactorum*, a fungus closely related to the one causing Norway maple canker and formerly believed the same. It attacks chiefly the maples, including the Norway, red, sugar, and sycamore maples; also the American beech, and, according to Fenska, the southern live oak (*Quercus virginiana*). Pirone found the first case of this disease in New Jersey in October, 1910.

The disease is named for its most characteristic primary symptom, the oozing of sap from fissures over-lying cankers in the bark. Infected inner bark, cambium, and sapwood develop a reddish-brown necrotic lesion, which commonly exhibits an olive-green margin. These symptoms differ markedly from those produced in trees affected with basal canker. A secondary symptom, the wilting of the leaves and dying back of the branches, is said by one investigator to be due to a toxic material secreted by the causal fungus.[5]

The disease has been controlled in a number of cases by trunk injection of a chemotherapeutant (diaminoazobenzene dihydrochloride). This substance, an organic dye, counteracts the toxins produced by the fungus.

[5] *Ibid.*, p. 249.

X

ENVIRONMENTAL DAMAGE AND MISCELLANEOUS TROUBLES

As it travels about from place to place, an animal receives various kinds of blows from a hostile environment. It may roll off a cliff, fall into a hole, become trapped in quicksand, acquire a thorn in its foot, etc. Since a tree cannot travel about, it would seem to be spared such blows of fortune. On the contrary, although it cannot go in search of adventure, adventure does not fail to come to it. A tree need not move to come into collision with objects; the objects will seek it out even though it be in the heart of a forest.

The kinds of mechanical and environmental damage that can happen to a tree seem almost unlimited. If in the woods, moose chew its bark off, beavers fell it, insects bore into its heart, termites honeycomb it, giant vines strangle it in their deadly caresses, fire consumes it, lightning splits it into a thousand pieces.

If in the city, its enemies, although different, are no less pernicious. As it stands along a city street, minding its own business, asking for nothing, bestowing the blessing of its shade and beauty on all with god-like impartiality, it would seem to be the one object in the world without enemies. Yet its enemies are legion. Insects work tirelessly to bring about its downfall, attacking roots, trunk, limbs, branches, twigs, leaves, and fruit, without quarter. Lawnmowers bump against it. Steam rollers pass under it, scorching its branches. Automobiles scrape and bump it and occasionally wrap themselves around it. High loaded trucks break its branches off as fast as they can grow out. Electric wires burn its leaves and branches. Children hack on it with knives and hatchets. Unthinking persons dump cement, kerosene, oil, and cinders around its roots. Storms break out its crown or split it down the center. Untrained tree workers climb in it with the climbing spurs of telephone linemen, or encircle split limbs with chains, bands, or cables.

Nearly everything in the environment tends to destroy the tree. It continues to live on only because of its strength, its adaptability, and its capacity for self-repair.

Some of the principal environmental hazards are discussed below.

FILL

Possibly the worst thing that can be done to a tree is to fill around its root system. As a tree grows, its roots become accustomed to a certain soil level. Through the soil they receive air, water, and food. Millions of microorganisms live in that medium, directly or indirectly assisting the tree to live. Whenever the relation of the roots to the soil level is changed, either by removing soil or adding to it, the tree feels the effect.

In cases where absolutely necessary, the grade level may be lowered or raised without ill effect if done gradually. "Gradually" means over a period of years. While a tree cannot adapt to sudden changes, it can adapt to gradual ones. If soil is gradually taken away and roots exposed (as often happens on the banks of streams), new roots will develop underneath. If soil is gradually added, particularly in first one section, then another, the existing roots will have time to adjust themselves to the new conditions.

But if the roots are suddenly exposed or suddenly covered over, damage is certain to result. Fill is even worse than exposure, although both are bad. Large quantities of dirt dumped around a tree suffocate it by shutting out the passage of air and water to its roots and by interfering with the function of the beneficial microorganisms. The harm is done, not by placing the dirt close to the trunk, but by spreading it out over the entire root region (roughly comparable to the branch spread).

The extent of the harm depends on the kind of tree, age of tree, type and amount of fill. Some trees, such as the post oak, are quickly killed by even small quantities of fill. Others, such as the live oak or the American elm, can survive several feet of fill. Young trees have much more adaptability than old ones. The least harmful kind of fill is loose, highly-porous soil permitting the passage of air and water. The worst kind is heavy, tightly packed clayey soil, a few inches of which are enough to kill most trees. The remedy is to use no fill, or if absolutely necessary, to use the most porous type possible (gravel, sand, sandy loam) and to the minimum depth. Feed and water the tree before putting down the fill.

ENCIRCLING CONCRETE

It is also an error to pour concrete or to erect rock walls close around the base of a tree. Many people do so motivated by the illusion that they are helping the tree. As a matter of fact, concrete near a tree is harmful in two ways: first, by preventing or hindering expansion of the trunk, second, by cutting off the water supply and interfering with normal soil conditions.

Concrete and plants are at all times highly antagonistic. Large areas of concrete around a tree are nearly always fatal to it, mainly for the resultant reduction of water to the roots and the interference with the free passage of air and the activities of minute organisms in the soil. Trees so entrapped seldom die suddenly, declining rather little by little over a period of years. Different kinds of trees offer different degrees of resistance to such a condition. Some will send their roots 150 or 200 feet in all directions in search of water.

Sometimes the tree wins and the concrete loses in the struggle. A concrete ring actually touching a tree trunk, unless unusually thick, is almost certain to be cracked by the enormous pressure exerted during the growing season. Where the tree is only flanked, not encircled, its roots bear the brunt of the defense. The heaving effect of large lateral roots is well known to all who have seen their sidewalks crazily tilted out of their neat mathematical bed when daring to approach too closely to certain kinds of trees, such as the cottonwoods or the elms. In extreme cases sidewalks may be entirely overthrown, in others merely cracked and raised. But the battle is an uneven one and as might have been expected, the forces of civilization almost always win. For the tree lover only one rule is safe: No large slabs of concrete near your trees.

LOW TEMPERATURES

A tree is considered "hardy" or "not hardy" according to its ability to withstand cold. Trees are hardy in relation to their natural environment, otherwise they would not be there. But a tree that is hardy south may not be hardy north; hence if it is planted north, it needs to be artificially protected during cold weather, or it will be killed. A tree that is hardy north will obviously not be harmed by cold if moved southward, although it may be harmed by the heat, the dryness, or other factors of an unfamiliar environment. Many tender trees are damaged or killed by unusual cold waves penetrating into their territory, such as happened to most of the southern states in 1917.

Even trees well adapted to northern latitudes, however, are sometimes damaged by the cold. The commonest kind of such damage is that produced by ice, snow, and freezing temperatures. Buds, twigs, and small branches are sometimes actually frozen, and their tissues destroyed. This is particularly true of new, succulent growth that sometimes forms during "Indian summers" (periods when hot weather is unseasonably prolonged) or that is forced out by late summer fertilizing. For this reason such late feeding should be avoided, as should severe shearing back of shrubbery or evergreens just before the advent of cold weather.

Another type of injury is the "frost crack," a longitudinal split which appears on trunks (and sometimes limbs) when sudden thaws follow freezing temperatures. These open with a loud report, like the sound of a gun fired; they may be a foot or a foot and a half long or even longer, several inches deep, and half an inch or an inch wide. They usually heal over during the following growing season, but may reopen during the next winter.

The interior of the wound should be protected with tree dressing.

If the wound seems likely to reopen, a threaded rod or bolt and nut may be run through the tree at that point.

LIGHTNING INJURY

Occasionaly a tree is struck by lightning. Since there are no statistics on the subject, it is impossible to say just what any given tree's chances are of being struck. Most of us have seen lightning-damaged trees; many of us have seen the actual striking. In any case, the phenomenon occurs often enough to keep it from being merely an academic possibility and often enough to justify the protection of valuable specimens by the installation of lightning rods. It is probably safe to say that in every electrical storm of any magnitude one or more trees are struck.

Some kinds of trees are more likely to be struck than others. The most susceptible kinds seem to be the oak, elm, pine, tuliptree, poplar, and ash; some of the shallow-rooted trees, like the maple, are seldom struck, while on the other hand the shallow-rooted willow and cottonwood are often struck because they are found on the borders of streams.

Again, other things being equal, isolated trees are more likely to be struck than those in a forest, and of those in a group the tallest is the most likely. Trees along the banks of streams are struck more often than those in drier situations. Trees near a house are sometimes struck to the possible salvation of the house. It is notoriously unwise to take shelter under trees during storms, because of danger of lightning as much as of falling limbs.

When lightning strikes a tree, it may utterly destroy it, destroy part of it, or merely burn off a strip of bark. Some struck trees recover entirely, some recover partly, some never recover. When the writer was a boy, lightning struck a large cottonwood in the lot adjoining his home, flinging pieces of limbs all over the neighborhood, one heavy splinter flying in his bedroom window and embedding itself in the wall three inches from where he lay sleeping.

Most trees struck are blasted from the top all the way down to the ground along one side in a strip that varies in width from six inches to a foot and a half. Even though the grain is spiraled, as in many of the oaks, the discharge follows the grain. Along the blasted area the bark, the cambium, and the sapwood are killed. The damage is caused partly by actual burning and partly by exploding steam generated in the tissues by the extremely high temperatures. After a few weeks the bark falls off, exposing the wood. In trees that have enough vigor left to recover, callus tissue slowly grows over the exposed wood in the years that follow.

Some trees are killed by one lightning blast, others can withstand several. Nearly all the oldest specimens among the redwoods and sequoias have been struck repeatedly through their thousands of years of growth, surviving with their great regenerative vigor these blows of fate as well as countless forest fires, insect plagues, drouths, floods, etc.

Valuable specimens may be protected with lightning rods. The installation is quite simple and inexpensive. Although no lightning rod is 100 per cent effective, the possibility of eliminating or lessening the danger is high enough to make the installation worthwhile.

After a tree has been struck, it is wise to wait a few months to see whether it will live before spending money on its treatment. Sometimes the roots are killed by the blast, in which case recovery is impossible. If the tree shows signs of continued vitality, however, it should be fed and watered generously; the dead bark should be scraped away, and the exposed wood painted with a good tree dressing. Damaged limbs should be strengthened by cabling.

WIND DAMAGE

High winds probably take as great a toll of trees as any other natural agency. They twist off limbs, destroy the whole crown, or blow over the entire tree. Unfortunately, there is not much that can be done to prevent such catastrophe. To protect other plants, trees are planted as windbreaks, but what can be planted to protect the trees themselves? Only other trees, it being obvious that trees in a group withstand wind better than trees individually.

High winds are serviceable in the sense that they break off limbs ready to fall anyway and blow over rotten trees that should have been removed six months before. Winds—and termites—are nature's instruments for the disposal of trees that are no longer useful.

Unfortunately, however, the wind sometimes takes the good with the bad.

Try to plant strong-wooded trees that do not break and split easily. Try to select trees with a naturally strong "U" crotch, or to train them to this form. Whenever possible, avoid the "V" crotch and above all the weak multiple crotch. Other things being equal, plant trees in the lee of other trees or houses, and so locate them that if they are blown over, they will not fall on the house (taking into account the prevailing winds).

In a large tree, cable together all major limbs. (See chapter on *Cabling.*) Leaning trees or shallow-rooted trees may be cabled to other trees. Trees with large cavities in the trunk particularly need this type of anchoring.

Prune trees judiciously. Cut back long, spindly branches one-third or half of their length. Reduce the top in top-heavy trees. Prune to distribute weight equally all around the trunk. Obviously, a one-sided tree is more likely to be blown over than a well-balanced one.

(An apparent exception to this rule is the case of trees that have grown up in regions where strong winds always blow from the same direction. Such trees are permanently deformed; their branches all on one side and all pointing in the same direction, and their boles permanently bent. Exposed to the buffetings of the wind from their infancy upwards, these trees have developed an exceptionally strong root system and are less easily blown over than straight, well-balanced trees grown in a more or less sheltered location. Such are the uses of adversity.)

SUNBURN

Incredible as it sounds, trees are occasionally affected by sunburn. Incredible, because we are taught that plants seek the light, and because trees are the shelters we get under to protect ourselves from sunburn.

But with sun, as with everything else, it is possible to have too much of a good thing. Too much sun and too little water will eventually kill any tree. When water is continuously transpired through the leaves and none taken in by the roots, the tree is gradually desiccated. In such cases the tree sheds its leaves in an effort to preserve itself, but under prolonged extreme conditions of drouth and heat, it dies.

Although this is damage attributable to the sun, sunburn proper is a little different. Sunburn, or sunscald, refers specifically to the injury done to bark tissues by direct exposure to the sun. A tree may die of desiccation without having its bark actually burned. On the other hand, a tree may die of sunburn although receiving and transpiring abundant water.

There are four different cases in which sunburn occurs: (1) On newly transplanted young trees whose tender bark is exposed to hot sun before they develop a protective crown of leaves; (2) on northern trees transplanted southward to regions of more intense sun; (3) on topped trees whose limbs are thus suddenly deprived of their umbrella of shade; (4) on trees, habituated to the dense side shade of clusters, suddenly exposed to the sun by the removal of the surrounding trees.

Note that in all such cases it is the suddenness of the change that does the damage. Trees, like other plants and animals, can adapt themselves to nearly anything if changes are made gradually, but when these are made too suddenly, the trees die before adaptation.

When sunburn is severe on the trunks of young trees, it not infrequently kills them. On large trees that are topped, the sunburn damage is usually limited to destroying the bark and cambium on the upper side of the limbs. To prevent these various kinds of damage, observe the following precautions:

(1) Whenever possible, transplant trees in rainy, cloudy weather.

(2) Wrap trunks and major limbs of all transplants with heavy crepe paper or loose burlap.

(3) Protect transplants with a semitranslucent canopy, such as the camouflaging material used during the war.

(4) Spread out the pollarding of a large tree over a period of two or three years, cutting parts of the limbs the first year, part the second and third years.

(5) Feed and water sunburned trees in order to stimulate quick new growth. Scrape away dead bark and paint all exposed wood.

HAIL

Severe hail storms sometimes damage trees, stripping off the leaves and injuring the bark. The bark on old trees is seldom injured, although leaves and twigs may be knocked off. On younger trees with tender bark, however, every hailstone leaves its mark. A week or so later the destroyed bark falls off, exposing the wood, usually along areas 3 or 4 inches long and 1 to 1½ inches wide. A young tree may show many scars of this nature, and the tree expert is frequently called on to diagnose the "mysterious new disease."

Little, if anything, can be done to protect against hail damage. Young trees can be partly protected by covering with a tarpaulin, although hail generally falls so suddenly that there isn't time enough for even this precaution. Fortunately damage to twigs and leaves is not severe, and the bark wounds are small enough to heal over very rapidly. On scars large enough to warrant it, the exposed wood should be painted.

ICE AND SNOW

Damage to trees by ice and snow is often very great, obviously greater in the North but not unknown in the South when exceptional cold waves penetrate those regions. In Dallas, for example, many fine trees were destroyed by ice, and others nearly destroyed, when freezing rains fell over Texas in the winter

The damage is caused by the accumulation of ice and snow on the branches and limbs until they break under the unaccustomed weight.[1]

Ice is worse than snow, for it is solid and it clings, while snow may be blown off or shaken off by the movement of branches in the wind. Evergreens, although in full leaf, often suffer less than broad-leaved trees because their structure allows them to bend with greater flexibility, and the peculiar arrangement of their branches allows the upper to rest upon the lower.

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[1] Apart from ice and snow, the only other things that weight down branches to the point of breaking them off are the fruits they themselves bear and the animals (or humans) that climb on them. The passenger pigeon is said to have alighted on trees in such numbers as to break off every branch. An old-time tall tale tells of a hunter in the early days of this country who found so many wild turkeys perched in a tree that it took him all day to shoot them. When he finally finished killing all the birds and turned to look for his wagon, he found it dangling fifty feet up in the air. Relieved of its load of turkeys, the tree had gradually straightened up, taking the horse and wagon, which he had tied to one of the limbs, up with it!—Applied to the passenger pigeon this story would very nearly be true.

The only preventive against ice and snow damage is adequate cabling and bracing. Ten dollars spent on cabling might save fifty dollars' worth of subsequent pruning, and might very easily prevent loss of the whole tree.

In regions where ice and snow are frequent, the planting of brittle trees should be discontinued and the planting of strong-wooded trees encouraged.

DUST, SOOT, AND SMOKE

Trees may experience two kinds of suffocation: suffocation of the roots by water or fill, and suffocation of the leaves by soot, dust, or other foreign material on the leaves and bark. The leaves, particularly on their lower surfaces, are covered with thousands of tiny openings, called *stomata,* through which water vapor and gases are exchanged. Similarly the bark is studded with openings called *lenticels* through which air and water vapor are allowed to pass. When either or both of these organs are clogged up, the tree suffers; in extreme cases it dies.

Trees growing in the forest seldom experience this type of suffocation. Rains, usually more frequent over a forest than over an urban area, keep the leaves washed clean and bright.

In a city, however, the conditions are just the opposite. Dust is kept in a state of constant agitation by the myriad automobiles. Although rain gives temporary alleviation, three or four hours afterwards the traffic dries the mud and churns it into dust. Trees along unpaved streets are commonly more white than green. Tree workers can hardly work in such trees because of the dust shaken off the leaves by their movements.

As bad as, or worse than, dust is smoke and soot. In industrial areas factory chimneys belch out uncountable cubic feet of poisonous gases daily. When atmospheric conditions are just right—or just wrong—the gases (smoke) and their residue (soot), instead of being [illegible] down [illegible]

[illegible] in these areas often [illegible] respiratory diseases. Should we not expect trees to [illegible]? They do, although their troubles do not often make headlines. Dust sometimes accumulates on leaves to such an extent that the tree dies or is seriously affected. Under such conditions growth is out of the question; mere survival is achievement. The harm is done in three different ways: (1) by clogging up the stomata and lenticels; (2) by reducing light intensity and hence reducing the tree's ability to manufacture food; (3) by poisoning the tree directly with sulfur dioxide gas.

Unfortunately little can be done to prevent the accumulation of dust and soot. Obviously, trees near paved streets in quiet residential areas have the advantage over those in dusty districts or near factories. Dust may be washed off trees with a hose and off small plants with a syringe. Soot may also be washed off, although to a lesser degree.

Trees with a waxy, shiny coating on their leaves are much less affected by dust and soot than others. The poplar, the ginkgo, and the tree of heaven are three of the best for planting in unfavorable regions.

WIRE AND CABLES

As explained in the chapter *Cabling*, there is a special way of attaching cables to trees—by insertion, not by encirclement. But since few people apart from tree experts are familiar with this method, it follows that trees continue to take a lot of punishment from wires, cables, chains, ropes, and everything else that can be wrapped around or wedged into them.

Almost nobody builds a fence without nailing it to or wrapping it around a tree. Trees are natural anchors for clotheslines, swings, hammocks, hanging flower-pots, etc. Even telephone and utility companies use trees to anchor their posts. Road-building and house-building crews put chains around trees to secure their equipment, [illegible] tree being the most solid object at hand. [illegible] every possible supporting, anchoring [illegible] rope sliding over the same [illegible]

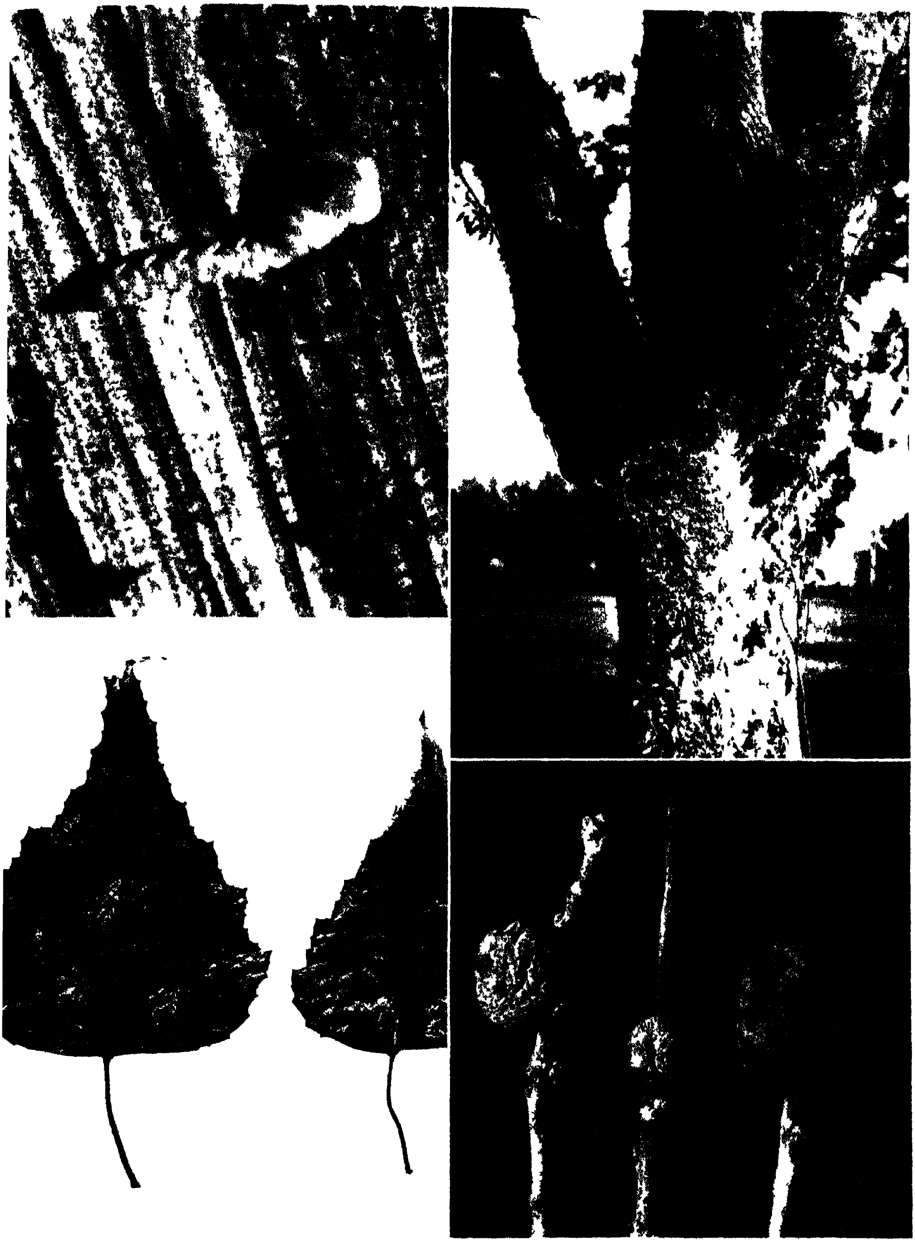

Plate 19. TREE TROUBLES *Upper left* Flat-headed borer on oak Although so soft it can be crushed between the fingers, it can eat its way through the hardest wood. *Upper right* Canker on hackberry This tree died a year later *Lower left* Leaf miner damage on leaves of gray birch Spring spraying is the only deterrent. (Courtesy of Connecticut Agricultural Experiment Station.) *Lower right:* Various twig galls taken from the same post oak.

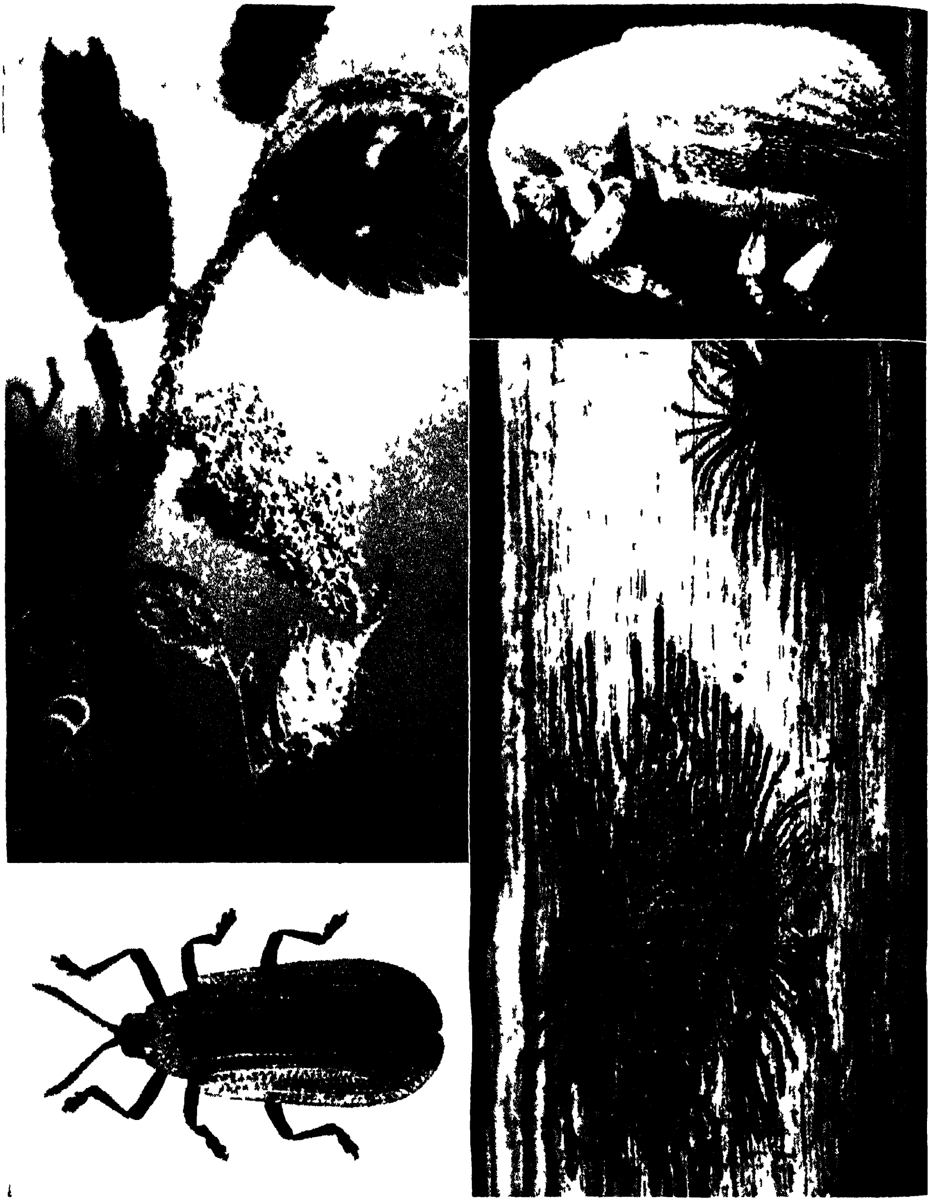

Plate 20 INSECTS AND TREES *Upper left* Plant lice on American elm. Spray cannot reach inner surfaces of curled leaves. *Upper right* European elm bark beetle (greatly enlarged), principal carrier of Dutch elm disease. *Lower right* Tunnels of American elm bark beetle, another carrier of Dutch elm disease. *Lower left* Locust leaf miner. Spring spraying would lessen its damage, which causes locust leaves to look dead in midsummer (Three photos by U S Dept. of Agriculture.)

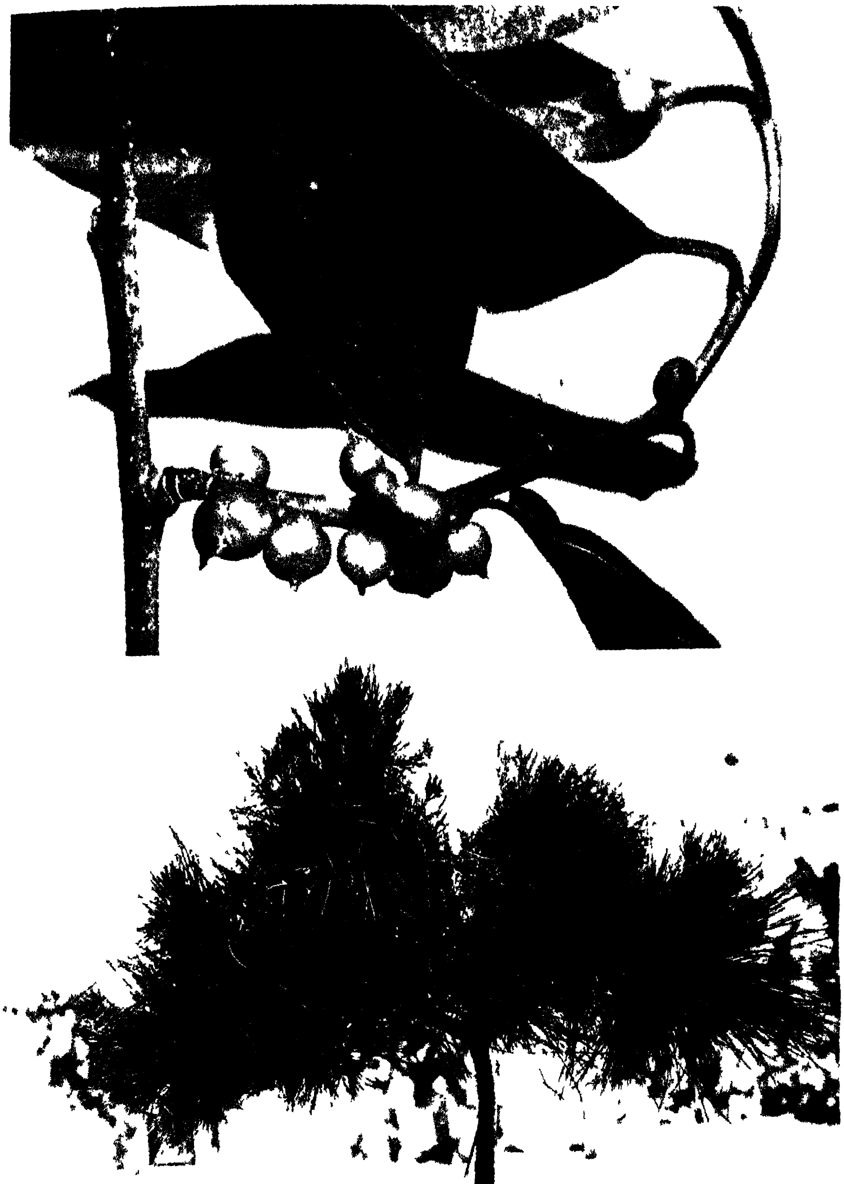

Plate 21. MORE RESULTS OF INSECT WORK. *Above* Twig and leaf galls on hackberry, caused by the sting of a tiny wasp. Larvae develop inside, then escape through the pores. Little harm is done. *Below.* Witches' broom on Austrian pine. Mites that infest leaf buds produce adventitious shoots instead of normal ones.

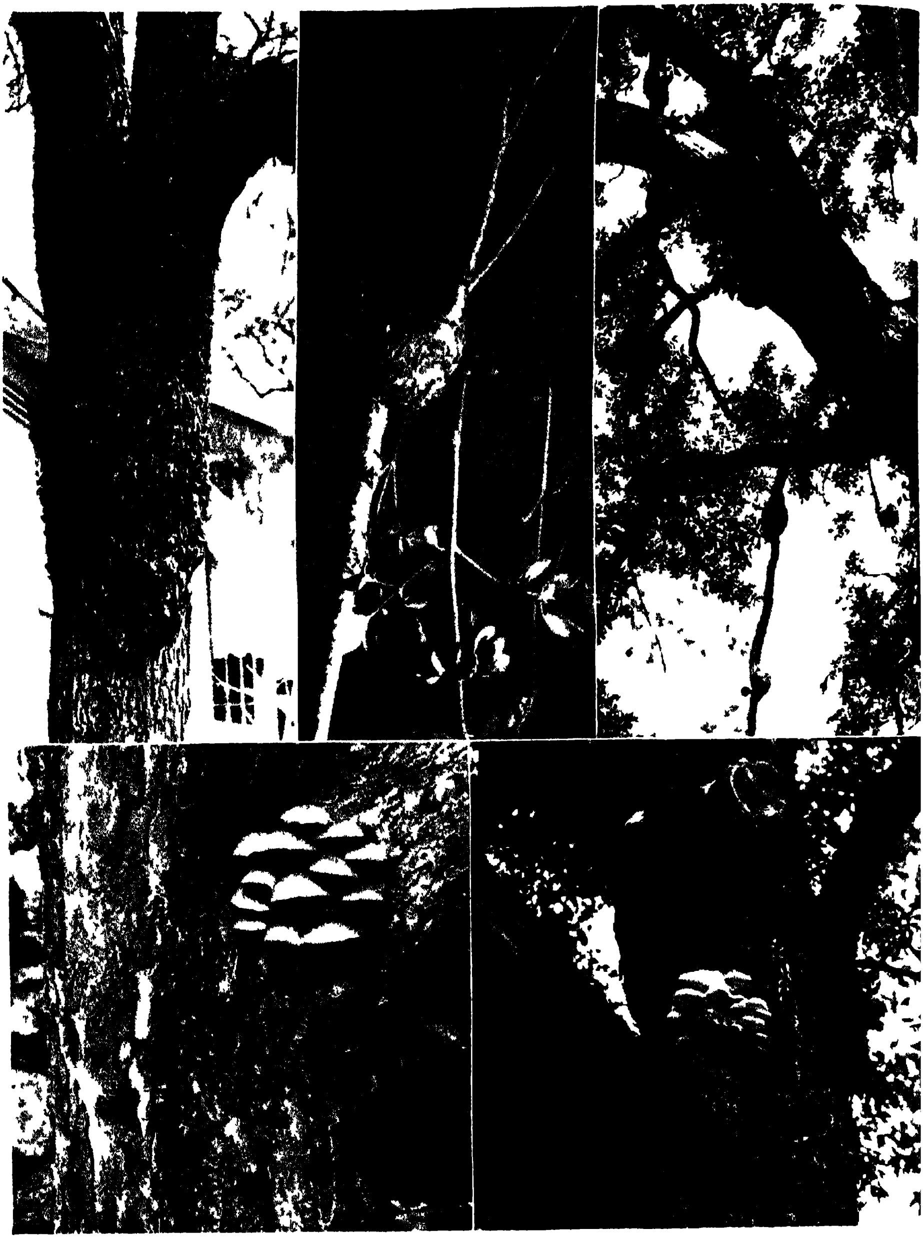

Plate 22 MISTLETOE AND MUSHROOMS. *Above, left to right* Tumorlike growth on Texas elm caused by mistletoe, small branches of which appear at right Mistletoe on Chinese elm Effect of mistletoe on pecan tree enlargement of branch with death of its terminal portion *Below* Heartrot of apple produced by the mushroom *Pholiota* (Courtesy F A Bartlett Tree Expert Co) Shelf fungus on hackberry, with entry gained through the branch stub.

wear away the wood. A large oak tree where Captain Kidd is thought to have buried his treasure still shows the scar of a rope burn where the treasure is said to have been lowered into a hole.

Chains or cables or heavy ropes sliding around a tree under strain slip the bark and cut into the wood. Left permanently tied on, they do even more harm, strangling the tree as it tries to keep on growing.

Wires are very commonly wrapped around trunk or limbs and forgotten. If the wire is thin and the tree vigorous, the tissues sometimes manage to bulge out around the wire and grow together on the other side of it. But if the wire is thick or wrapped doubly, and the tree is in poor vigor, the tree is frequently killed.

If you have any wires, cables, chains, bands, or ropes encircling your trees, remove them at once. (Parts of wire already embedded in the tree are best left in, for by pulling them out new wounds are opened.) Do not wrap anything around your trees. Attach clothes-lines, hammocks, etc. with lag screw hooks as explained in detail in the chapter *Cabling*.

EXTRANEOUS GROWTHS—MISTLETOE

In warmer parts of the country, one of the most harmful of parasites is mistletoe, an interesting and attractive plant in its own right but a most undesirable guest on your lawn trees. Mistletoe sends its roots (haustoria) directly into the live tissues of the host tree, living on the nourishment it can draw therefrom. Although green and active photosynthetically, mistletoe cannot live in the soil. It must live parasitically, and trees are its chosen victims. At the point of attack, the tree limb or trunk swells up, sometimes to twice or thrice its normal size, but from that point onward the limb atrophies and usually dies.

Quite commonly in areas where the parasite abounds, trees are seen with many short bare limbs, each terminating in [illegible] to [illegible] swelling, these represent [illegible] limb [illegible] remaining. Many trees [illegible] to themselves [illegible] by cutting [illegible] normal growth, this condition being actually caused by the deformation of tissues at the point of infestation.

More than any other kind of tree, hackberries, naturally tortuous to begin with, show this gnarled and twisted effect. Hackberries and elms are most commonly parasitized; mesquites, pecans, walnuts less so; oaks very rarely. Among the oaks the blackjack oak is attacked more often than the others, the post oak seldom, the live oak almost never. The rarity of mistletoe on oak trees is the basis of many superstitions among primitive peoples of all races. As the bringer of good or bad luck, the symbol of this, that, or the other, it is as exceptional and portentous an occurrence as an eclipse or an earthquake. Sir James Frazer in *The Golden Bough* tells the story in detail.

Dwarf mistletoe often produces "witches' brooms" on trees. (See page 156.)

Mistletoe may be removed mechanically by sawing it, cutting, or breaking it off. It is most conveniently removed by sawing, since some large masses, which come to weigh as much as 100 pounds, develop semiwoody stems of considerable toughness. Removal of the aerial parts, however, does not usually kill the plant, which soon sends up new shoots from the roots (haustoria) inside the host. Once the parasite has firmly established itself, it travels through the host tissues and becomes capable of sending up shoots at points several feet from the place of original infection. Small branches badly infected should be removed entirely.

New infections are caused by birds which, eating the plant's attractive white berries, carry the sticky seeds from twig to twig in their beaks or on their feet or feathers, or deposit them with their droppings.

Mistletoe grows slowly but very tenaciously. In addition to deforming limbs, it weakens them to the point where they may break in time of stress. Moreover, it appears to make the regions it has invaded more susceptible to attack by insect pests and other diseases.

In Australia experiments have been made to test the extent of mistletoe's damage to eucalyptus trees. Radioactive salts injected into the trunks were later traced by Geiger counters and found to have lodged 100 per cent within the masses of mistletoe, thus indicating the extent of the absorptive powers of the parasite.

No effective chemical or biological remedy against mistletoe has yet been found. However, very recently, promising results have been obtained (1) by spraying with the various weed-killers and similar chemical preparations, and (2) by injecting chemical substances into the host trunk in an attempt to destroy the internal parts of the parasite. Although highly gratifying, this work is still in the experimental stage.

EPIPHYTES

Apart from the parasites, there are other plants that grow on trees, which should be removed at the time of pruning, or at any other time when they threaten to become a menace. There is a large category of plants which, instead of rooting in the ground, grow upon trees or other plants, using them as support, but not drawing nourishment from their tissues. These strange plants are called epiphytes or air plants. They are not parasites, since they manufacture their own food, drawing sustenance from mineral particles largely dissolved in rain water in the air, rather than from the soil. Their roots do not enter the tissues of the plant they grow upon as do the haustoria of mistletoe, but serve only to anchor the plant to its "host," exactly as the tendrils of ivy cling to a wall.

Among the most interesting of all plants, the epiphytes, while rare in colder climates, abound in the semitropical and tropical zones. In this country, Texas, Louisiana, Mississippi, Florida, and southern California have a fair showing of epiphytes, but to see them in their full glory it is necessary to visit Mexico, Central America, and other hot countries of much precipitation. It is in such places that they attain their greatest size and greatest variety, not infrequently being more attractive than the anchor plant itself, growing upon it so profusely as to exclude it from the sight, and to exclude it also from light and air and hence eventually to cause its death. For this is the evil of the epiphytes: although not actually parasitizing trees, they sometimes grow upon them so thickly as to smother them, and therefore must be considered noxious, except in small quantities.

VINES

Vines, although neither parasites nor epiphytes, are as bad for a tree as either. Sometimes they are worse, for a tree may live on for many years in spite of the combined attacks of parasites and epiphytes, but it will be killed in the space or two or three years by the unchecked growth of certain vines.

Because they derive no nourishment from the trees upon which they twine, the common vines are not parasitic; they are not epiphytic because they have roots in the ground rather than in the air. A vine uses a tree simply and purely for support, and it grows equally well against a house or a fence, on a wire trellis, or on a telephone pole. It damages a tree in a negative rather than a positive sense—not by drawing anything out of it directly but by shutting it out from light and air, by spreading its exuberant canopy out into and over the space which the tree's leaves had marked out for their own.

There are certain vines naturally more limited or more open in their habits of growth which twine upon trees but do not kill them. Others, and these are the majority, bring certain death within a few seasons. But even when they do not kill, they stunt; hence all vines must be set down as injurious to trees and should be removed from them at least down to the point where the limbs branch out from the trunk. On the trunk itself, if it is sound, a vine does no harm. The danger is in forgetting to keep it under check and allowing it to climb up among the branches. Even on the trunk, if the bark has been damaged in any way, a vine may hold moisture and so cause the exposed wood to decay. If you love your trees the best rule is: No vines.

LICHENS

Lichens are extremely interesting plants found growing on rocks, fallen logs, old buildings, and the trunks and branches of most trees. They make themselves visible as small irregularly shaped patches or splotches of grayish-white, closely appressed against trunk or rock. When wet, their color may change through various shades of gray, white, and green.

Since they are so frequently found on tree trunks, many people believe them parasitic, or at least symptomatic of some obscure disease. Actually, lichens are neither parasites, nor fruiting bodies of fungi, nor colonies of insects nor any one of the many other fantastic things for which they are commonly taken: they are combinations of algae and fungi growing together in a partnership mutually beneficial. Roughly it may be said that the alga, containing chlorophyll (and hence giving the plant its greenish color), manufactures food for the union, while the fungus provides the structural supporting network. The partnership has proved a very successful one, for lichens exist throughout most of the world, sometimes as long, drooping filaments (Old Man's Beard), sometimes fleshy, flower-like lobes (reindeer moss), more often as scaly incrustations on rocks and tree trunks. When examined closely, they are seen to be beautiful little plants, intrinsically of the highest interest and absolutely harmless to trees, except in the very rare cases where they occur in such superabundance as to interfere with the lenticels on the bark of new limbs or young trees.

Where considered objectionable, they may be simply scraped off. Ordinarily, however, they add interest to the tree on which they grow, and for those who are attracted by miniatures, form a microcosmos complete within themselves. Called by John Ruskin "the first mercy of the earth," they soften the rock, populate the wilderness, and lend venerableness to the gnarled and twisted trunk.

MOSSES AND FERNS

Mosses as well as lichens frequently adorn tree trunks. The true mosses are members of the phylum Bryophyta,[2] and rated "lower" in the botanical scale than the flowering plants (Spermatophyta) to which the epiphytic bromeliads going by the names of "ball moss" and "Spanish moss" belong.

Mosses are familiar to most people because of their habit of growing on rocks on the borders of streams. They are green, soft, and velvety. Unlike lichens, they cannot stand extremes of heat and drouth. On the contrary, they thrive in cool, shady, moist places; hence they are found near streams, on decaying logs in the forest, on shingles where the sun is not too intense and the rainfall is frequent (in Jalapa, Veracruz, the red-tiled roofs are beautifully softened with moss); and, more apropos to our subject, on trunks of living trees. Most temperate-zone trees are host to at least a small quantity of moss. It does absolutely no harm, being neither parasite nor saprophyte, growing upon the tree as it grows upon rock. It is rather an adornment than otherwise, and we can think of no legitimate reason for taking it off.

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[2] Some of the "mosses" on trees are algae.

Certain kinds of ferns are also sometimes found growing on trees. Like mosses, ferns are strictly epiphytic, manufacturing their own food and using the tree only as an anchor; hence, like other epiphytes, they do no harm unless they occur in such numbers as to crowd out leaves. In tropical forests epiphytic ferns are commoner, larger, and much more numerous. With us they are so rare that the presence of one should be received with rejoicing, not misgivings.

GIRDLING ROOTS

All dicotyledonous trees expand in girth as long as they live, not because they want to but because they have to. Given the principles of their construction, they have no choice. Hence when a wire or cable is wrapped around a tree, it does not cut into the tree, to speak strictly, but the tree moves out against it and actually brings about its own strangulation.

The same effect is brought about even more strangely in the case of girdling roots. A girdling root is a root that somehow grows out of its normal position and comes to wrap itself around the trunk or around the taproot or around one of the large lateral roots at the ground line or slightly below. In this case the root is like an encircling wire, with the difference that the root and the trunk *both* increase in diameter, until a point comes when the root may completely strangle the tree.

Some girdling roots are caused by poor planting practices: the roots crammed into a hole too small for them so that they intercross and twist around on each other. Others are caused by unfavorable environmental conditions, such as proximity to a street, a rock wall, etc., which induces the roots on that side to double back on themselves in search of more favorable feeding areas.

The only remedy for girdling roots is to remove them with mallet and chisel, as shown in the picture on Plate 24. When such roots are below the ground level, they are, of course, harder to discover. When a tree is in a declining condition from no visible cause, the possibility of a girdling root should not be overlooked. In some cases the taproot may be strangled two or three feet under the ground by an erratic side root.

CHLOROSIS

Deficiency of one or another essential nutrient of trees is often revealed by chlorosis, or yellowing of the foliage. The pattern and intensity of the yellow coloring indicate the nutrient that is in short supply, and this in turn reveals which element is lacking in the soil.

The most common type of chlorosis involves a deficiency of nitrogen. Since the compounds of nitrogen make up from 40 to 50 per cent of the dry matter of protoplasm, ample nitrogen is of the greatest importance to plants. Furthermore, certain nitrogen compounds are very mobile within the plant and may be translocated from old to young plant tissue. Any deficiency of nitrogen must therefore be immediately corrected if a plant is to develop normally. A good general fertilizer with an analysis of 6–10–4, 5–10–5, or 4–8–6 is considered remedial for nitrogen deficiency.

Probably the next most common nutrient deficiency is that of iron. Iron is a somewhat important constituent of oxidizing enzymes. It is relatively immobile in plant tissue. There is evidence that the amount of chlorophyll in plants is related to the amount of active iron present.

As a remedial compound, iron sulphate has been used with good results. Other iron compounds are available on the market and should be used according to instructions on the containers.

Recently a number of "chelating" compounds have appeared. The value of these compounds lies in their ability to form stable complexes with iron and other metals, and hold them in a form which will make them readily available to the tree.

In the case of pin oaks, soil applications of iron sequestrene complex mixed in the upper six inches of soil have initiated the development of new leaves in bunches near the branch terminals of chlorotic trees. This new development took place within three weeks after application of the compound.

Other nutrient deficiencies may exist, but the trees utilize the remaining essential nutrients in such small amounts that the soil generally contains a sufficient supply for the life span of the tree.

BLEEDING AND SLIME FLUX

Many trees bleed or drip from pruning wounds or bark injuries. Some trees, such as most of the oaks, horsechestnut, basswood, pine, and spruce, never or seldom bleed. Some bleed slightly but soon cease to do so. Others, such as mesquite, hard maple, birch, walnut, yellowwood, and American elm, bleed profusely. In most cases, the bleeding does not seriously affect the tree (except as discussed below), but since many homeowners are disturbed by it and since the sap drip frequently falls on sidewalks, parked automobiles, or other objects, the tree expert is often called upon to stop it.

Unfortunately, little can be done to control bleeding. Trees that are natural bleeders will bleed even out of correctly made pruning cuts painted over with the best of paints, while trees that are not natural bleeders will not lose a drop out of the ugliest stub. The profuse bleeders should not be pruned when dormant but only when in full leaf. In this manner the bleeding is lessened because most of the sap goes to the foliage. (In nonbleeders pruning is best done in winter or in early spring.)

When the bleeding drips directly onto the ground, it does little or no harm. When, however, the wound stands in such relation to the limb or trunk it occurs on, that the drip or ooze runs down these, it produces what is called *slime flux*. Slime flux is unsightly, malodorous, and harmful to the tissues it flows over.

There are two kinds of flux: (1) brown slime flux, which originates out of the heartwood sap, and (2) alcoholic slime flux, which originates from the sap of bark and the sapwood. Although the two kinds may occur together, it is commoner for only one kind to occur at a time.

As the sap issues from the tree, it is a more or less clear liquid, but the starches and sugars it contains attract large numbers of bacteria, fungi, yeasts, and insects, which rapidly ferment it into a white, foul-smelling solution. The acids and aldehydes in the solution are toxic to the tree tissues they flow over, destroying bark and cambium.

Treatment is difficult. If the flux comes from a pruning cut or bark wound, this should be properly shaped so as to facilitate rapid healing. If it comes from the bottom of a filled cavity, this should be reopened for further treatment, and a drain pipe should be installed. Many arborists char the face of the wound with a blow torch, then seal it with an extra coat of asphalt.

Recent experiments indicate that persistent bleeding of elms, and to a lesser extent of other trees, is often caused by a bacterial disease to which the name "wetwood" has been given. This disease affects the sapwood and/or heartwood, producing fermentation and resulting in high pressure which forces the sap out through pruning cuts, bark wounds, etc. Sometimes the infected sap is carried up into the branches where it may cause curling, drooping, wilting, and even loss of leaves.

Treatment of slime flux consists of boring an upward-slanting hole in the tree below the place where the flux is coming out and installing a piece of pipe to carry the drip away from the trunk. The hole should pass through the heartwood and well into the sapwood on the opposite side. The pipe should be inserted just far enough to seat firmly; if inserted too far, it will not drain the sap that accumulates in the region through which it passes. The hole-and-pipe treatment, while not a cure, prevents injury to the trunk and usually prevents the toxic sap being carried up into the branches. Sometimes the pipe may be advantageously installed at or near the ground level or even underground.

INJURY BY ANIMALS

Although we think of insects as the forms of animal life most commonly attacking trees, it should not be forgotten that quadrupeds, and even birds, also do a certain amount of damage.

In the woods many wild animals chew the bark, sometimes entirely girdling the tree, especially in times of famine. Moose, deer, rabbits, squirrels, and other rodents are the principal offenders in this respect.

In urban areas most of these animals are of course ruled out; but not all of them. In the northern parts of our country, in the Rocky Mountain areas, and even in the densely populated eastern states, animals tend constantly to encroach upon civilization, as civilization has encroached upon them. People living in outlying parts of a city, in suburban areas, or on farms, are sometimes surprised, particularly in times of prolonged cold and snow, to find deer tracks around their bark-stripped trees.

Squirrels, rabbits, and field mice are common in most urban areas. Squirrels in particular seem to be everywhere. They chew off tender bark, bite off twigs, and crack or harvest all the nuts they can get to. In the south they are considered a plague to all owners of pecan trees, who have invented some interesting guards to keep them off, in the shape of bands of tin wrapped around the trunks, flared out at the top like lamp-shades, after the manner of rat guards on ship hawsers. Squirrels and opossums live in tree cavities. Although they do little, if anything, to enlarge the cavities, they often prevent the mouth of the hole from growing together by their constant entering and leaving.

Dogs often damage plants and young trees with their urine. Various chemical preparations on the market are effective in repelling them. A wire cage around a young tree is also recommended.

Birds do most of their damage to fruit trees, eating the crop before we have a chance. The choicer the fruit, the better they seem to like it. Of many trees they eat the seeds, and of some the buds. In summary, however, the good they do by eating harmful insects so far outweighs the bad that we could easily afford to plant extra fruit trees exclusively for their benefit.

Some people believe that woodpeckers injure trees by drilling their nesting holes in them. Actually, they drill only into already rotten or semirotten trees. Most of their time is spent hopping up and down the tree trunks, not looking for new places to drill holes, but searching out and eating the wood-boring larvae.

PAINT INJURY

Some kinds of paints can damage or even kill trees, particularly young ones with tender bark. Certain oil paints will kill smooth-barked trees, such as hard maple and sycamore of a foot or less in diameter, if applied in a complete circle. Creosote, although an excellent wood preserver, should not be used on live trees, as it kills bark and cambium very quickly. It may be used sparingly to treat the inactive center of an old pruning cut or the exposed heartwood of a cavity, but it should be kept away from the margin of the live tissue. Paints with tar or tar derivatives are usually toxic to tree tissues, and should be avoided.

Various preparations are on the market for banding trees to help control insects that crawl up from the ground. Some of these contain toxic ingredients. When used on old trees, no harm is usually done, unless the bark is scraped off too much before its application. When used on young trees with thin, tender bark, death is sometimes the result. If desired to be used on young trees, the danger may be obviated by first wrapping the trunk with burlap or some similar material, then spreading the substance over this.

Most commercial tree paints have an asphalt base with some antiseptic ingredient added. Asphalt—not the same as tar—is completely harmless to the tree. Roofing compounds made of asphalt mixed with asbestos fibers may be used safely for filling small holes; putty and plastic wood are also possible in this instance.

Sometimes good paints are made harmful by the addition of toxic diluents. Petroleum oils should never be used as diluents—certainly not kerosene. Turpentine is acceptable, but the safest thinner of all is linseed oil, itself a vegetable product.

Pine oil, widely used by veterinarians for painting dehorning wounds and even flesh wounds, is an excellent tree paint that should be more widely used.

Orange shellac is recommended for painting exposed cambium at the edge of pruning cuts or newly opened cavities.

SALT-WATER INJURY

Trees living near the ocean are sometimes injured by blowing salt spray. Trees living very near the beach, such as the palms, are of course acclimated to saltiness of the air and saltiness of the soil —in fact, can hardly live without it. But those trees living farther back which do not normally receive salt spray through the air are injured when it does accidentally reach them. This occurs rarely, of course, only during exceptionally strong and prolonged winds. The hurricane of 1919, for example, carried salt spray 100 miles inland over much of New England, damaging trees and shrubs over a wide area.

The damage shows up as a discoloration of foliage, followed by a shedding of leaves, and a terminal die-back of new shoots. If it occurs in the wintertime, buds may be destroyed so that spring leafing out is considerably delayed. Tender plants may be killed outright. The harm is done by the "drawing action" of the salt, which extracts so much water from the leaf and twig tissues that they shrivel and die. Trunks and large limbs are usually protected by their rough bark.

Against such an eventuality there is no control, except to move inside, or to shield in some way, the smaller plants. Damaged twigs should be clipped off.

ILLUMINATING GAS INJURY

Escaping illuminating gas is a very common cause of tree injury. Poor construction of gas mains or their breakage by heavy traffic or the gradual loosening of their joints makes possible a slow seepage of gas that is very toxic to tree roots.

Where the leak is slight, symptoms show up as a gradual yellowing and dropping of foliage and the gradual dying of branches near the top. Where the leak is large and sudden, the symptoms are easier to diagnose. The foliage of all affected trees turns yellow almost overnight, branches die back rapidly; and if no relief is given, the bark becomes loose and fungus growths may appear on the trunk.

There are two ways of confirming the diagnosis: (1) by the odor test; (2) by the tomato plant test. Where the soil is saturated, the gas odor may be very strong. If it is not noticeable on the surface, it may be detected by punching 3- or 4-foot holes into the ground. If not perceptible at the mouth of the hole, the leak is probably very small.

The tomato plant is even more sensitive than the human nostrils. Where leaks cannot be detected by smelling, dig a hole two feet deep in the suspected area and set a potted tomato plant in the hole, cover over tightly with a board, and leave for 24 hours. When the plant is removed at the end of that time, its stems will be bent sharply downward if any gas is in the soil. (The bending is not wilting but a growth response to the ethylene factor in the gas.) If the plant is unaffected, you may assume there is no escaping gas in the vicinity. If tomato plants are not available, sweet pea or carnation plants may be used instead. If gas is present, it will usually prevent buds from opening and cause open flowers to close.

If the tree is not too far gone when the leak is detected, it may be saved by taking the following steps. First, ask the gas company to repair the leak immediately. Second, dig a trench on the side of the tree nearest the leak and replace vitiated soil with new soil. Third, punch holes all over the root area and blow out gas with compressed air. Fourth, flood the whole root area with water to help wash away toxic materials. Fifth, prune out dead branches and cut away dead or diseased roots. Sixth, feed the tree to encourage the development of new roots.

Where a tree has been killed by gas, it should be removed by the roots and the ground should be thoroughly spaded up and allowed to stand idle several months before anything else is planted in the same place.

Gas leaks occurring in the winter when the surface is frozen over very frequently kill nearby trees, since the gas cannot leak through to the surface.

INJURY BY LACK OF WATER

Perhaps the commonest cause of tree injury is lack of water. Trees, like animals, must have water, or they cannot live. Water makes up the bulk of their substance; without it their tissues shrivel and die. Water is the circulating medium by means of which food particles are transported within the tree's body. Without water neither photosynthesis nor respiration would be possible. Without water a tree will die even in the most fertile of soils, for it cannot utilize food that is not first dissolved.

The largest and finest trees occur in regions of abundant rainfall: in our northeastern woods, in the Ohio River basin, along the Pacific Coast, in the tropical rain forests, etc. Contrariwise, the poorest and most stunted specimens occur in the desert regions.

Abundant water means not only large trees, it means green healthy leaves and full tops, while lack of water means shedding of leaves and dying of branches.

The most usual cause of lack of water is, of course, sub-normal rainfall. When rainfall is less than normal over any given region, trees suffer. Their suffering may be alleviated to a greater or lesser degree by artificial means, but it cannot be relieved entirely.

City trees sometimes suffer from lack of water even when rainfall is normal. This may happen: (1) when surrounded by asphalt, cement, or other substances impervious to the passage of water; (2) when roots are cut or damaged by street-building or house-building, and the reduced root system becomes inadequate to absorb the necessary moisture; (3) when roots are damaged by toxic substances in the soil; (4) when roots are covered by non-porous fill; (5) when roots are covered by heavy sod; (6) when the contour of the land is changed so that water runs off before it can soak in.

The remedy in each of these situations is to change the existing condition and to furnish the tree with an adequate supply of pure water.

Trees may be best watered by making holes in the root area with a punch bar and applying water directly through them. This method is particularly valuable where heavy sods are present. Where the grass is thin or spotty, watering may be done from the surface. Slow soakings two or three times a week are better than sudden floodings. Sprinkling is of little value.

Signs of water deficiency are leaf scorch (browning of leaves around the edges), leaf wilting, sparseness of foliage, appearance of dead twigs, premature shedding of fruits, leaves, or twigs, and stagheading (appearance of large dead branches in the top).

A tree can be killed by too much water as well as too little. Where there is a clay substratum, water from above may be unable to drain through and so accumulate to such a degree that the tree roots drown. Most trees cannot grow in a soil constantly saturated, and if the water content of a soil is suddenly and greatly increased, affected trees may die before they have a chance to adapt to the changed conditions.

CHEMICALS IN THE SOIL

Certain chemicals may contaminate the soil to such an extent that tree roots are poisoned. The accumulation of contaminants may be sudden or gradual. Some of the commonest contaminants are salt, kerosene, motor oil, calcium chloride, cinders, and, more recently, weed killers.

Salt is sometimes carelessly spilled near trees. Ice-cream freezers are sometimes emptied, and even sand piled along the parkway may contain salt that leaches down to the roots.

Home-repair jobs on automobiles often result in the emptying of kerosene, motor oil, or gasoline in the tree root area.

Calcium chloride, often used on country roads to help keep down dust, may be washed into the tree root region, causing severe damage.

The increasing use of weed killers has caused damage and death to some trees. Many of these substances are specifically designed to kill brush as well as weeds, and their careless or indiscriminate use has naturally resulted in injury to good trees.

Unweathered cinders or "clinkers" may be harmful if piled around trees because of the toxic ingredients gradually washed down to the roots.

In places where trees or other plants near trees are sprayed frequently over a period of years the poisons contained in the spray may accumulate in the soil to such a degree that toxic effects are produced. This is particularly true in certain soils, such as sandy loam, and particularly noticeable in shallow-rooted trees, such as fruit trees, because of the greater accumulation of poison in the upper layers of soil. Damage to apple trees as a result of the accumulation of arsenicals in the soil was noted as early as 1908. Contaminated soils gradually decrease in contamination when left fallow.

Although most of the information on soil contamination by spraying concerns the arsenicals, we now have enough evidence about the new insecticides to show that some of them, such as DDT, BHC, chlordane, aldrin, dieldrin, methoxychlor, do persist in the soil to the extent that repeated use may build up harmful residues. It will be the task of research chemists to develop new materials equal to these in effectiveness but nonaccumulative in the soil.

DAMAGE BY FIRE

Fire and trees are incompatible elements and should never be brought together except in the fireplace. Most of us are aware of the great losses sustained annually because of forest fires. Statisticians agree that fire is the greatest single enemy of the tree.

Even city trees are occasionally damaged by fire. Leaves or trash are frequently burned near them, singeing the foliage and damaging the branches. Sometimes the fire is made directly against the trunk, in which case the bark and cambium are killed over a considerable area. Cases are known where a fire built at the bottom of a hollow tree to smoke out a 'possum has resulted in the sudden burning of the whole tree, the central cavity forming a perfect draught, like a chimney, and the dry wood on the inside serving as tinder.

Where houses burn down, surrounding trees are often damaged. Those very close to the fire are usually killed, those farther away are burned on the proximate side. Damaging heat usually carries much farther than the flames proper, so that even trees that seem to be out of range may be injured.

Burnt branches should be pruned back to the nearest live lateral. Twigs that are only lightly singed should be given time to come out again before clipping off. Burnt bark will usually fall off, exposing the sapwood, which should be painted. Where the bark is damaged but too lightly burned to fall off, it should be removed surgically. Badly burned trees should be fed and watered to hasten bark development over injured areas.

ATOM BOMB DAMAGE

What the atom bomb does to trees is rapidly becoming history, although fortunately none in our country have yet been destroyed. Trees near ground zero are utterly destroyed. Those farther away are broken by the high wind and burned by the heat; those still farther away are burned only.

Trees and other plants whose tops were destroyed in the Hiroshima and Nagasaki bombings quickly sent up a marvelous secondary growth—a luxuriance of vegetation which soon re-covered the desolate landscape. Apparently this effect was due to atomic radiation of the plant roots.

XI

QUESTIONS AND ANSWERS

CONCERNING SOME POPULAR BELIEFS

Q. How can a stump be kept from resprouting?

A. Although salt and kerosene were formerly the two materials most commonly used, they are not as effective against stubborn trees as chemicals more recently developed. One commonly used is ammonium sulfamate in the form of crystals which may be poured into downward-slanting holes bored into the stump or into cuts made along exposed roots. The crystals are dissolved in the sap and carried by the sap flow to all parts of the tree. Another is the hormone type of chemicals, particularly 2,4-D and 2,4,5-T. If the basal area from which new shoots would rise is thoroughly soaked with one or both of these combined with fuel oil, the chances are good that the stumps of even the most persistent trees will be killed.

Q. Can a tree be killed by driving a copper nail into it?

A. No. This is a popular fallacy. Although copper is poisonous to plants, including many fungi, and is for this reason the chief ingredient in many fungicide sprays, it is not, in low concentration, harmful to trees. Copper in solution is sprayed directly onto a tree for disease control; it kills the molds and rusts but leaves the tree unharmed.

Similarly, copper nails, although firmly embedded in tree roots, trunk, or limbs, produce no ill effect.

Q. Is a fruit tree helped to bear fruit by driving iron nails into its trunk?

A. Very little, if at all. Although this is a time-honored practice, not enough iron to have an appreciable effect is absorbed by the tree in this manner. To induce a tree to bear fruit when it is suffering from iron deficiency, punch-bar feeding in the soil is recommended today. This has the additional advantage that other elements as well as iron may be supplied.

Q. Why do some trees have flowers while others seem to have none?

A. Practically all trees have flowers, for without flowers they cannot develop seeds, and without seeds the reproduction that is the chief aim of their lives would, for many trees, come to end. We are misled into thinking that some trees do not flower because their flowers are inconspicuous. Those of the American elm, for example, are seldom noticed, yet this tree unfailingly flowers and forms seed each year—often while snow is still on the ground, weeks before other trees awaken from their winter nap.

Q. Why are some trees said to be male and others female?

A. In some species, such as the willows and cottonwoods, "male" (staminate) flowers are borne by some individuals, while "female" (pistillate) flowers are borne by others. Thus, some trees may legitimately be called male and others female, although when neither flower nor fruit is present, it is impossible to tell one from the other, there being no secondary sexual characteristics. A species in which the two kinds of flowers occur on separate plants is called *dioecious.* A dioecious species will not set fruit and seed unless a male and female tree are fairly close together, so that pollen may be carried from male to female by wind or insects.

In other groups of trees such as the oaks, separate male and female flowers are borne on the same tree but in different places. Such a tree is said to be *monoecious.* Even when standing alone it is generally capable of setting fruit and seed.

Other trees, especially those with showy bloom, may have both male and female parts combined in each individual flower. These are known as *perfect* flowers. A still different situation exists in the maples, in which there may be separate staminate and pistillate flowers as well as perfect ones.

Q. Are woodpeckers harmful to trees?

A. Only the sapsucker. Most birds are, of course, beneficial to trees because of the large number of insects they eat. High on the list of beneficial birds are the woodpeckers, which destroy borers and other harmful insects.

The sapsucker, however, has brought the woodpecker family into disrepute. It makes a series of small holes along the bark in horizontal rows, actually eating the bark and cambium. It comes back day after day to reopen the holes and to eat the insects that collect around them. By thus making many holes close together and by keeping them open, it kills some trees and damages many others.

Q. Do squirrels harm trees?

A. Very little. Although squirrels live in tree cavities, they do not make the cavities but take possession of those that already exist. By constantly entering and leaving their homes, however, they prevent the mouth of the cavity from growing together. Also their scampering up and down trunks sometimes tears away the bark, particularly on young trees or very smooth-barked ones. In the wintertime when food is scarce, they have been observed to chew off twigs.

On the whole, their damage is very small and certainly is more than offset by the interest and animation they lend to the tree in which they choose to live.

Q. Must a transplanted tree be set in the same relation to the points of the compass as it was growing before being moved?

A. No. If it were necessary, all trees and plants growing in nurseries would have to have their stems marked North, South, East, West, so that when moved, they would be planted in exactly the same orientation. Thus a plant could not be turned with its most presentable side forward unless that side happened to face the same way as in the plant's native home. Some persons foolishly carry out this practice in setting out their own trees, while altogether neglecting the rule that a tree should be set at the same depth at which it was naturally growing.

THE GROWTH OF TREES

Q. When do a tree's new leaves start to form?

A. Generally at least a year before they expand. The buds of *this* year's leaves were formed in *last* year's spring. When you see this year's leaves unfolding, *next* year's leaves are developing, in miniature, in the angle between the base of the leaf stalk and the branch or stem. They will remain snugly curled up as axillary buds all through late spring, summer, fall, and winter, ready to come out next year when calendar and weather give the signal. Thus, the process is repeated endlessly, the leaves being always ready a year beforehand.

Q. If a mark is made on a young tree at a certain distance above the ground, say three feet, will that mark remain in the same place or will it rise as the tree grows?

A. It certainly is natural to believe that a tree grows all over, and that just as a baby's knee gets farther and farther from the ground as he grows into a man, so a certain point on a tree trunk ought to get farther and farther from the ground as it grows. But a tree grows in height *only at the twig tips,* never along the whole length of its trunk.

The only way the trunk grows is in diameter: in common with all comparable parts of the tree—the limbs, the branches, and the twigs—it continually thickens as long as it lives. Thus, a mark of some kind made on the bark of a young tree will move *outward,* not *upward,* as the tree grows.

Q. How is it possible for a tree, when its top is cut off or damaged, to produce new shoots along its trunk and main branches where none grew before?

A. Such new shoots come from dormant buds that are scattered over much of the tree's surface. Though they normally remain in a resting state, they are always ready for activity in an emergency. When a tree is topped, new shoots develop rapidly from these resting buds. It is the abundance of such buds that makes willows often reproduce themselves from a broken-off branch.

Q. At what age does a tree stop growing?

A. A tree never stops growing. Unlike animals, which cease their growth at maturity, trees continue to grow as long as they live. Growth in old trees, however, is much slower than in young ones.

Some trees, such as the palms and the yuccas (monocotyledons), after reaching a certain size, grow only at the tip, getting taller but not thicker. All our commonest trees, however, such as oak, elm, hickory, cottonwood, etc. (dicotyledons), continue to get both taller and thicker every year of their lives. The trunk and branches increase annually in girth, and the twigs grow annually in length.

Q. Is there any way to tell the age of a tree other than by counting its rings?

A. Counting the rings is the only accurate way. Estimates based on size are only approximations, since growing conditions may change greatly during the life of a tree. However, it is no longer necessary to cut down a tree to examine its rings. Lumbermen use increment borers, which drill a small hole into the tree and bring out a core section. The rings are clearly visible in this section, as are also the tree's inner condition: whether sound, rotten, checked, stained, etc. The hole (usually less than half an inch in diameter) is readily stopped up with asphalt, putty, or cement, and the tree remains unharmed.

THE WELFARE OF TREES

Q. When is the best time to work on trees?

A. That depends in part upon the work to be done, in part on the immediacy of the need. In general, *pruning* may be done at any time, although pruning wounds made early in the spring heal over somewhat more rapidly by taking advantage of the subsequent growing season. Sometimes pruning is best done when leaves are on, to better distinguish live from dead wood. Many trees are advantageously pruned when dormant. Profuse bleeders, however, such as the walnuts, birches, yellowwood, and hard maple, should be pruned only when in full leaf.

The widespread idea that pruning should be done only in the dormant season is a carry-over from the days in which pruning was synonymous with dehorning. It is quite true that radical topping should be done only when the tree is dormant. By now, however, the term "pruning" has acquired a different meaning, and the removal of dead branches and a minor number of live ones may be done at any time.

Cavity repair may be done at any time and should be begun as soon as the cavity is discovered. However, since growth occurs most rapidly in the spring, cavity fillings set in at that time will be most quickly sealed over at their edges by the healing callus.

Cabling and *bracing* may be done at any time and should be done as soon as the need is discovered. Cables installed when the tree is in full leaf may sometimes become slack when the leaves fall off, although slight slackness is not objectionable. Cabling is often most practiced in the spring to repair the damage done by ice storms, but logically it would be better done before the storms.

Spraying is almost always done through the spring and summer as insects appear and plagues develop. However, some valuable preventive spraying can be done during the dormant season, in late winter or just before the buds break.

Removals can, of course, be made at any time. But it should be remembered that trees without leaves are smaller, easier to cut, and easier to haul away.

Planting is usually done in fall or spring. In regions of severe cold it is best deferred until spring. In the South it may be done any time after the leaves fall off; one month of the winter is as good as another. Moist, cloudy days are best for transplanting.

In the spring, planting should be undertaken before the buds begin to swell, since the roots will have become active several weeks earlier. Bare-rooted trees are better not moved after leafing out, although careful digging and stripping off of leaves sometimes makes the move possible. Since evergreens are always moved with a ball of earth, one time is about as good as another. Theoretically, any tree, evergreen or deciduous, can be moved at any time if a large enough ball of soil is moved with it. In practice, however, the cost of moving a large enough ball of earth to accommodate a deciduous tree in full leaf makes it wiser to wait until the leaves are gone.

Probably the worst time to move any tree is in late summer: when the spring growth impulse is nearly exhausted and before dormancy has set in.

Fertilizing is best done in early spring so that its effect may be immediately felt. It is less effective in midsummer and autumn and not effective at all, of course, in the winter, although not lost, since the materials remain in the soil ready to enter the roots in early spring. Heavy fertilizing right before the advent of freezing weather should be avoided because it forces new growth and keeps older tissues succulent at a time when they may be harmed by the cold. However, a sick tree should be fed and watered whenever its sickness is discovered, regardless of the season.

Q. What is the largest tree that can be transplanted?

A. Theoretically no tree is too large to be transplanted. It is merely a question of getting enough roots and of having the heavy equipment necessary to handle the large masses and great weights involved. Trees are usually moved with a ball of earth that measures eight to twelve inches in diameter for every inch in diameter of the tree's trunk. This means that a four-foot tree would need a 40- to 48-foot ball—extremely difficult and costly, but not impossible.

Trees a foot, foot and a half, and two feet in trunk diameter represent the upward levels in accepted practice among experienced arborists. Generally the sizes are smaller. Deceptively small though it may seem, even a three- or four-inch tree is a job for a professional. Most nurseries sell trees not larger than three inches in trunk diameter.

Q. Will it save my tree from the ill effects of fill to build a stone well around it?

A. No. The roots of a tree extend through an area roughly corresponding to the spread of its branches and sometimes far beyond. Just as leaves are found at the tips of twigs and not along the trunk or the major limbs, so the root hairs, the real feeders, are found near the tips of the roots and not along the great muscular roots close to the trunk. Hence building a well two or three feet distant from the trunk with hope of preventing root suffocation from fill is almost entirely useless. Its most helpful service is to keep the trunk bark from rotting, as it sometimes does when earth is banked against it.

Q. Does it make any difference where a limb is cut off?

A. It makes all the difference between good and bad work. A limb should be cut off at a joint, flush with the trunk of the tree if it stems from the trunk, or flush with the lines of whatever limb it does stem from. If a stub or lip is left, the tree cannot heal around it. Such stubs usually decay and, if not cut off or chiseled out, provide an avenue by which disease organisms may enter the body of the tree. Small twigs or twig tips, on the other hand, may be cut off almost anywhere. Since they contain much embryonic tissue, they will usually send out clusters of new shoots below the cut.

YOU AND YOUR TREE MAN

Q. Is it better to have tree work done on a contract basis or a cost-plus basis?

A. It is better on a cost-plus basis. While laying bricks or building automobiles may be worked out at an invariable price per unit, work on trees cannot be so worked out. Each tree is different: a different size, a different kind, and in a different condition. No man that lives can name to the hour the time it will take to prune or repair a given tree. The homeowner, however, often does not realize this, demanding that tree work, like other forms of labor more easily calculable, be contracted on a flat-rate basis. By so doing, he exposes himself to two dangers: (1) the danger of being overcharged, as when the arborist, forced to name a flat figure, protects himself by charging more than he actually expects the bill to be on a cost-plus basis; and (2) the danger of getting a poor job, as when the worker, anchored to a figure from which he cannot pull loose, skimps on the work when it turns out to be more than he had bargained for.

The homeowner should make up his mind in advance that good work cannot be secured at bargain prices and should put behind him for all time the seductive illusion of the lowest bid.

In buying an article of merchandise, price may legitimately enter into the decision, other factors being equal. Even in building a house, it is common practice to accept the lowest bid, since the architect is on hand to see that the contractor meets all the specifications. But tree work is different. Here the homeowner has no architect and no inspector to protect his interests. He must rely entirely on the integrity of the arborist, and the arborist, however honest, cannot be expected to put forth his best efforts when he finds himself coming out financially on the little end.

Q. How can I tell a reputable tree man from an unreliable one?

A. This question naturally arises out of the preceding one. Reputable arborists fortunately seem to be on the increase, in part because of the efforts of the National Shade Tree Conference, which strives constantly to raise standards among tree workers and serves as a nerve center for the dissemination of information.

In tree work, as in other businesses, the majority of long-established companies are reliable. The questionable workers are the itinerants without telephone or address, men who drift in and out with far more interest in your money than in your trees. Beware of door-knockers, unlettered trucks, phony references, and glib talkers.

Much can be inferred from the worker's equipment. Adequate equipment in good condition indicates a prosperous past usually (but not always) synonymous with a long record of satisfied customers.

Many times information about a man can be supplied by the local Chamber of Commerce, the Better Business Bureau, or the County Agricultural Agent. A good indication of reliability is membership in the National Shade Tree Conference.

Gradually, better educated men are getting into tree care. Graduates of schools of forestry or men who in some way have made a special study of the subject are obviously better prepared than those who have learned the work merely by rule of thumb.

Q. How can I tell whether my tree is properly repaired or not?

A. It is hoped that reading this book will help you to answer that question. So few people know anything about trees that competent judges of the work are as scarce as competent workers. One of the curious features of tree work is that a man may do it badly and never be detected, for who is there to expose him? If a plumber repairs your hot water heater or a mechanic your car motor, you know within a few days whether the work was properly done; the results speak for themselves. But if an unscrupulous tree man gives you third-quality work, you may never discover the fact. Trees have such great regenerative power that they often survive all the injuries that ignorance and malice can heap on them, just as a human patient may struggle on for years in the hands of a charlatan doctor. Unfortunately, tree surgery is crowded with charlatans—men who without training or conscience get into it because they see a chance to make easy money, capitalizing on the public's lack of knowledge. Encouraging, however, is the slow but steady spread of knowledge in the form of books on trees, garden encyclopedias, horticultural magazines, etc. Nevertheless, at the present time it is no exaggeration to say that the public knows more about stars or the atom bomb than about trees. If anyone is really interested in the fate of his trees, he must make an effort to learn for himself.

TREES AND THE LAW

Q. Do I have a right to cut off limbs from my neighbor's tree when they are overhanging my property?

A. Yes. According to law, you do have a right to cut such limbs back to the point where they intersect your property line. You also have a right to cut any encroaching roots. Moreover, you may do so without notifying the owner of the tree or asking his consent However, the parts cut off belong to the owner of the tree and must be given to him if he so requests.

In the case of fruit trees, the fruit legally belongs to the owner of the tree, and (if the limbs have not been cut off) he has a right to reach over on the adjoining property and pick the fruit. (Hoffman *v.* Armstrong, 46 Barb. (N.Y.) 337.)

Q. Does my neighbor have a right to mutilate or cut down a tree on the boundary line between our properties?

A. No. Nor do you. Such a line tree belongs to both parties and, according to a ruling of a New York court, may not be mutilated or destroyed by either party without consent of the other. If either party acts contrary to this ruling, the other may sue for treble damages.

Q. Am I liable if my tree falls over on my neighbor's property?

A. If you can be proved negligent in any respect, you are liable for damage. If the tree is decayed or weakened or split or damaged at its roots and you have been apprised of its condition, or if you are presumed to have been aware of its condition, then you are considered negligent. On the other hand, if the tree was apparently sound and no negligence on your part can be proved, then the fall is considered an act of God, and you are not liable.

In many cases the testimony of a tree expert is needed to help decide whether the owner could have been reasonably supposed to have been aware of the tree's impaired condition. Where considerable damage is involved, this point can be a delicate one.

Q. Do I have a right to remove trees in the parkway in front of my property?

A. Parkway trees (those between the sidewalk and the street) are in many communities considered city property and hence are not removable without permission of the city authorities. In municipalities that retain a city forester the parkway trees cannot be removed or worked on without permission from the forester's office, and the men who are to do the work must be licensed by that office. In other communities the city has its own crew charged with maintenance and removal of parkway trees.

In smaller communities that do not have a city forester, the parkway trees, although technically owned by the city, are sometimes planted, cared for, and removed by the property owner at his discretion.

Q. If the parkway trees in front of my property are injured, can I recover damages?

A. Yes. Although the trees may belong to the city, you have a special interest in them and may recover damages to the extent that accidental injury or willful abuse practiced on them lessens the value of your property. (Murtaugh *v.* Chicago Motor Coach Co. 269 Ill. App. 290,

Q. Is damage done to trees and shrubs deductible from my income tax?

A. Yes. According to Section 23 (e) 3 of the Federal Revenue Act of 1938, trees and shrubs are considered an integral part of the entire estate and not a separate entity. For this reason damage done by storms, lightning, hail, etc., may be deducted from the income tax, the amount of the deduction being the difference in appraised value of the estate before and after the casualty.

Q. Who has control over trees along the highways?

A. Along state highways the State Highway Department has full jurisdiction over such trees. Although sometimes the departments get the help of private tree organizations, they more often use their own crews for planting, repairing, and removing. Along county roads the procedures vary from state to state and locality to locality.

XII

TOOLS, EQUIPMENT, AND BOOKS

THE HOME-OWNER hobbyist or the beginning tree surgeon often has difficulty finding the proper tools. Since most tree tools are highly specialized, hardware stores stock only the simpler items. Feed and seed stores carry a limited stock of shears, saws, and other simple tools. Usually it takes the tree expert years to accumulate the necessary equipment, often being forced to manufacture some of the tools himself or to have them manufactured to his own design.

This condition is rapidly changing, however. Keeping pace with the constantly increasing number of tree workers, there have appeared a number of special manufacturers and distributors who handle complete supplies of garden, nursery, and tree expert tools and materials. A. M. Leonard & Son, Inc., of Piqua, Ohio, has a large and varied stock. The Fanno Saw Works, Chico, California, makes nearly all kinds of tree saws. Atkins, Disston, Bartlett, and other large manufacturers make tree saws and pruners, which may be obtained, by special ordering, through most hardware stores. J. E. Sebrell, Los Angeles, California, sells pruners, pole saws, fruit pickers, hooks, and other attachments for mounting on lightweight aluminum poles.

Best known power saws are the Disston, Mall, McCullough, Timberhog, Lombard, Titan, Atkins, Homelite, Woodsman, I.E.L., Precision, Woodboss, Reed-Prentice, Poulan, Hornet. Most of these are gasoline powered, others are electric. Chains for these saws and files to sharpen the chains may be obtained from the Oregon Saw Chain Corporation, Portland, Oregon.

Extension ladders can be bought in hardware stores or lumber yards. Aluminum or magnesium ladders can usually be bought or ordered in the same places. Specially built ladders are available from A. M. Leonard & Son, Inc., Piqua, Ohio; Howard Ladders, Kent, Washington, or Los Angeles, California; Dayton Safety Ladder, Cincinnati, Ohio.

Paints, ropes, cavity slicks, cabling equipment, and nearly all miscellaneous items are supplied by A. M. Leonard & Son, Inc., Piqua, Ohio.

Hand sprayers are stocked by hardware stores, feed and seed stores, also Montgomery Ward and Sears, Roebuck.

Power sprayers are available from John Bean Manufacturing Co., Lansing, Michigan; F. E. Myers & Brothers Co., Ashland, Ohio; Fitzhenry-Guptill Co., Cambridge, Mass.; Hardie Manufacturing Co., Hudson, Michigan; Niagara Sprayer and Chemical Co, Middleport, N.Y.; Universal Power Sprayer Co., Plymouth, Michigan; Friend Manufacturing Co., Gasport, New York.

Tree-moving trucks or trailers are manufactured by Gar Wood Industries, Inc., Detroit, Michigan; Charles F. Irish Company, Cleveland, Ohio; J. G. Butts Manufacturing Co., Cato, New York; Modern Equipment Co., Plainfield, Indiana; Rock Creek Nurseries, Rock Creek, Maryland; Williams & Harvey Co., Kansas City, Kansas; Ryan Landscaping Equipment Co., St. Paul, Minnesota.

Books, like saws and shears, are tools. Many people who would like to read about tree care have considerable difficulty finding books on the subject. Public libraries have a few (too few). University libraries have some. Book stores, while they may not stock the titles, can order any book in print.

Some of the best books on the subject are the following: *Maintenance of Shade and Ornamental Trees,* revised edition, by P. P. Pirone, published by Oxford University Press, New York; *The New Tree Experts Manual,* by Richard R. Fenska, published by A. T. de la Mare Company, New York; *Practical Tree Surgery,* by Millard F. Blair, Christopher Publishing Co., Boston, Mass.; *Insects and Diseases of Ornamental Trees and Shrubs,* by E. P. Felt and W. H.

Rankin, published by Macmillan, New York. The last two are out of print, hence can only be obtained in libraries.

In addition there are the many excellent bulletins published by the United States Department of Agriculture, covering almost every phase of tree diseases, insect damage, recommended trees for planting, etc. There are the detailed, explicit bulletins put out by the Department of Forestry covering the practical aspects of tree surgery. There is the U.S.D.A. Miscellaneous Publication No. 657, *Insect Enemies of Eastern Forests*, which omits no insect worthy of mention.

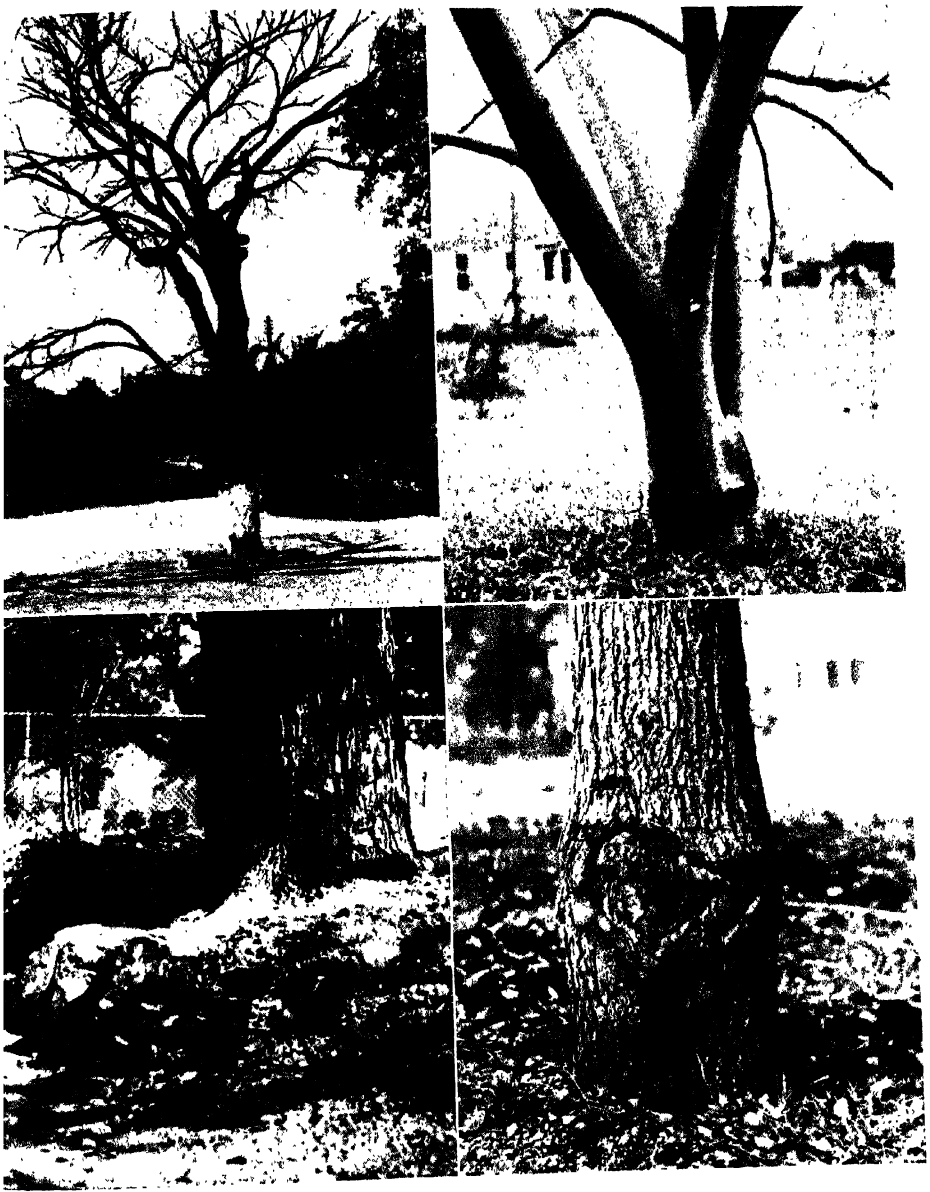

Plate 23. AVOIDABLE DAMAGE. *Upper left:* Suffocation. The asphalt patio has kept from the roots all water, air, and food. The small rock well does not give access to the tree's distant feeder roots. *Upper right:* Repeated lawnmower onslaught around the circumference may soon kill this tree. *Lower left:* Roots chopped off by sidewalks not only deprive a tree of half of its feeders, but seriously impair its anchorage. *Lower right:* Automobile damage. Diseases may enter through the wound made by scraping the tree in backing out of the garage day after day.

Plate 24. *Upper left:* Canker on oak trunk. When it spreads all the way around, the branch or the tree will die. *Upper right.* Wisteria vine on an elm tree. The thick vine canopy will eventually kill the tree by cutting off its light. *Lower left.* Trees banded with a sticky substance The band should be thick enough to entangle crawling insects and high enough to be out of reach of children. It is effective only against insects which do not fly. *Lower right* A girdling root which might kill a tree by strangulation can be removed surgically.

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